CHAPTER 6

ELECTRICAL AND ELECTRONICS PRINTS

When you have read and understood this chapter, you should be able to answer the following learning objectives.

- *Describe shipboard electrical and electronics prints.*
- *Describe aircraft electrical and electronics prints.*
- *Explain basic logic diagrams on blueprints.*

This chapter is divided into two parts: electrical prints and electronics prints. Each part deals with the use of prints on ships and aircraft.

ELECTRICAL PRINTS

A large number of Navy ratings may use Navy electrical prints to install, maintain, and repair equipment. In the most common examples, Navy electrician's mates (EMs) and interior communications electricians (ICs) use them for shipboard electrical equipment and systems, construction electricians (CEs) use them for power, lighting, and communications equipment and systems ashore, and aviation electrician's mates (AEs) use them for aircraft electrical equipment and systems. These prints will make use of the various electrical diagrams defined in the following paragraphs.

A PICTORIAL WIRING DIAGRAM is made up of pictorial sketches of the various parts of an item of equipment and the electrical connections between the parts.

An ISOMETRIC WIRING DIAGRAM shows the outline of a ship or aircraft or other structure, and the location of equipment such as panels, connection boxes, and cable runs.

A SINGLE-LINE DIAGRAM uses lines and graphic symbols to simplify complex circuits or systems.

A SCHEMATIC DIAGRAM uses graphic symbols to show how a circuit functions electrically.

An ELEMENTARY WIRING DIAGRAM shows how each individual conductor is connected within the various connection boxes of an electrical circuit or system. It is sometimes used interchangeably with SCHEMATIC DIAGRAM, especially a simplified schematic diagram.

In a BLOCK DIAGRAM, the major components of equipment or a system are represented by squares, rectangles, or other geometric figures, and the normal order of progression of a signal or current flow is represented by lines.

Before you can read any blueprint, you must be familiar with the standard symbols for the type of print concerned. To read electrical blueprints, you should know various types of standard symbols and the methods of marking electrical connectors, cables, and equipments. The first part of this chapter discusses these subjects as they are used on ships and aircraft.

SHIPBOARD ELECTRICAL PRINTS

To interpret shipboard electrical prints, you need to recognize the graphic symbols for electrical diagrams and the electrical wiring equipment symbols for ships as shown in *Graphic Symbols for Electrical and Electronic Diagrams*, ANSI Y32.2, and *Electrical Wiring Equipment Symbols for Ships' Plans*, Part 2, MIL-STD-15-2. Appendix 2 contains the common symbols from these standards. In addition, you must also be familiar with the shipboard system of numbering electrical units and marking electrical cables as described in the following paragraphs.

Numbering Electrical Units

All similar units in the ship comprise a group, and each group is assigned a separate series of consecutive numbers beginning with 1. Numbering begins with units in the lowest, foremost starboard compartment and continues with the next compartment to port if it contains familiar units; otherwise it continues to the next aft compartment on the same level.

Proceeding from starboard to port and from forward to aft, the numbering procedure continues until all similar units on the same level have been numbered. It then continues on the next upper level and so on until all similar units on all levels have been numbered. Within each compartment, the numbering of similar units proceeds from starboard to port, forward to aft, and from a lower to a higher level.

Within a given compartment, then, the numbering of similar units follows the same rule; that is, LOWER takes precedence over UPPER, FORWARD over AFT, and STARBOARD over PORT.

Electrical distribution panels, control panels, and so forth, are given identification numbers made up of three numbers separated by hyphens. The first number identifies the vertical level by deck or platform number at which the unit is normally accessible. Decks of Navy ships are numbered by using the main deck as the starting point as described in *Basic Military Requirements,* NAVEDTRA 12043. The numeral 1 is used for the main deck, and each successive deck above is numbered 01, 02, 03, and so on, and each successive deck below the main deck is numbered 2, 3, 4, and so on.

The second number identifies the longitudinal location of the unit by frame number. The third number identifies the transverse location by the assignment of consecutive odd numbers for centerline and starboard locations and consecutive even numbers for port locations. The numeral 1 identifies the lowest centerline (or centermost, starboard) component. Consecutive odd numbers are assigned components as they would be observed first as being above, and then outboard, of the preceding component. Consecutive even numbers similarly identify components on the portside. For example, a distribution panel with the identification number, 1-142-2, will be located on the main deck at frame 142, and will be the first distribution panel on the port side of the centerline at this frame on the main deck.

Main switchboards or switchgear groups supplied directly from ship's service generators are designated 1S, 2S, and so on. Switchboards supplied directly by emergency generators are designated 1E, 2E, and so on. Switchboards for special frequencies (other than the frequency of the ship's service system) have ac generators designated 1SF, 2SF, and so on.

Sections of a switchgear group other than the generator section are designated by an additional suffix letter starting with the letter *A* and proceeding in alphabetical order from left to right (viewing the front of the switchgear group). Some large ships are equipped with a system of distribution called zone control. In a zone control system, the ship is divided into areas generally coinciding with the fire zones prescribed by the ship's damage control plan. Electrical power is distributed within each zone from load center switchboards located within the zone. Load center switchboards and miscellaneous switchboards on ships with zone control distribution are given identification numbers, the first digit of which indicates the zone and the second digit the number of the switchboard within the zone as determined by the general rules for numbering electrical units discussed previously.

Cable Marking

Metal tags embossed with the cable designations are used to identify all permanently installed shipboard electrical cables. These tags (fig. 6-1) are placed on cables as close as practical to each point of connection on both sides of decks, bulkheads, and other barriers. They identify the cables for maintenance and replacement. Navy ships use two systems of cable marking; the old system on pre-1949 ships, and the new system on those built since 1949. We will explain both systems in the following paragraphs.

OLD CABLE TAG SYSTEM.—In the old system, the color of the tag shows the cable classification: red—vital, yellow—semivital, and gray or no color—nonvital. The tags will contain the following basic letters that designate power and lighting cables for the different services:

C	Interior communications
D	Degaussing
F	Ship's service lighting and general power
FB	Battle power
G	Fire control
MS	Minesweeping
P	Electric propulsion
R	Radio and radar
RL	Running, anchor, and signal lights
S	Sonar
FE	Emergency lighting and power

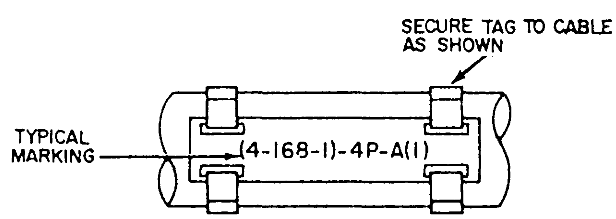


Figure 6-1.—Cable tag.

Other letters and numbers are used with these basic letters to further identify the cable and complete the designation. Common markings of a power system for successive cables from a distribution switchboard to load would be as follows: feeders, FB-411; main, l-FB-411; submain, 1-FB-411A; branch, 1-FB-411A1; and sub-branch, l-FB-411-A1A. The feeder number 411 in these examples shows the system voltage. The feeder numbers for a 117- or 120-volt system range from 100 to 190; for a 220-volt system, from 200 to 299; and for a 450-volt system, from 400 to 499. The exact designation for each cable is shown on the ship's electrical wiring prints.

NEW CABLE TAG SYSTEM.—The new system consists of three parts in sequence; source, voltage, and service, and where practical, destination. These parts are separated by hyphens. The following letters are used to designate the different services:

C Interior communication

D Degaussing

G Fire control

K Control power

L Ship's service lighting

N Navigational lighting

P Ship's service power

R Electronics

CP Casualty power

EL Emergency lighting

EP Emergency power

FL Night flight lights

MC Coolant pump power

MS Minesweeping

PP Propulsion power

SF Special frequency power

Voltages below 100 are designated by the actual voltage; for example, 24 for a 24-volt circuit. For voltages above 100, the number 1 shows voltages between 100 and 199; 2, voltages between 200 and 299; 4, voltages between 400 and 499, and so on. For a three-wire (120/240) dc system or a three-wire, three-phase system, the number shows the higher voltage.

The destination of cable beyond panels and switchboards is not designated except that each circuit alternately receives a letter, a number, a letter, and a number progressively every time it is fused. The destination of power cables to power-consuming equipment is not designated except that each cable to such equipment receives a single-letter alphabetical designation beginning with the letter *A*.

Where two cables of the same power or lighting circuit are connected in a distribution panel or terminal box, the circuit classification is not changed. However, the cable markings have a suffix number in parentheses indicating the section. For example, figure 6-1 shows that (4-168-1)-4P-A(1) identifies a 450-volt power cable supplied from a power distribution panel on the fourth deck at frame 168 starboard. The letter *A* shows that this is the first cable from the panel and the (1) shows that it is the first section of a power main with more than one section. The power cables between generators and switchboards are labeled according to the generator designation. When only one generator supplies a switchboard, the generator will have the same number as the switchboard plus the letter G. Thus, 1SG identifies one ship's service generator that supplies the number 1 ship's service switchboard. When more than one ship's service generator supplies a switchboard, the first generator determined according to the general rule for numbering machinery will have the letter *A* immediately following the designation. The second generator that supplies the same switchboard will have the letter *B*. This procedure is continued for all generators that supply the switchboard, and then is repeated for succeeding switchboards. Thus, 1SGA and 1SGB identify two service generators that supply ship's service switchboard 1S.

Phase and Polarity Markings

Phase and polarity in ac and dc electrical systems are designated by a wiring color code as shown in table 6-1. Neutral polarity, where it exists, is identified by the white conductor.

Isometric Wiring Diagram

An isometric wiring diagram is supplied for each shipboard electrical system. If the system is not too large, the diagram will be on one blueprint while larger systems may require several prints. An isometric wiring diagram shows the ship's decks arranged in tiers. It shows bulkheads and compartments, a marked centerline, frame numbers usually every five frames, and the outer edge of each deck in the general outline of the ship. It shows all athwartship lines at an angle of 30 degrees to the centerline. Cables running from one deck to another are drawn as lines at right angles to the centerline. A single line represents a cable regardless of the number of conductors. The various electrical fixtures are identified by a symbol number and their general location is shown. Therefore, the isometric wiring diagram shows a rough picture of the entire circuit layout.

"Figure 6-2 (four pages at the end of this chapter) shows an isometric diagram of a section of the ship's service and emergency lighting system for a DLG." This figure shows the forward quarter of the decks concerned, whereas the actual blueprint will show the entire decks. Note the reference to another isometric diagram at the top of the figure. It shows that the diagram of the complete lighting system for this ship required two blueprints. All electrical fittings and fixtures shown on the isometric wiring diagram are identified by a symbol number as stated previously. The symbol number is taken from the *Standard Electrical Symbol List*, NAVSHIPS 0960-000-4000. This publication contains a complete list of standard symbol numbers for the various standard electrical fixtures and fittings for shipboard applications. For example, look at the distribution box symbol 615 located on the second platform starboard at frame 19 (fig. 6-2). It is identified in NAVSHIPS 0960-000-4000 as a type D-62A four-circuit distribution box with switches and midget fuses. Its federal stock number is 6110-152-0262.

Cables shown on the isometric wiring diagram are identified by the cable marking system described earlier in this chapter. In addition, cable sizes are shown in circular mils and number of conductors. Letters show the number of conductors in a cable; S for one-, D for

Table 6-1.—Color Code for Power and Lighting Cable Conductors

System	No. of Conductors in Cable	Phase of Polarity	Color Code
3-phase ac	3	A B C	Black White Red
	2	AB	A, black B, white
	2	BC	B, white C, black
	2	AC	A, black C, white
3-wire dc	3	+ +/-	Black White Red
	2	+ and +/-	+, black +/-, white
	2	+/- and -	+/-, white -, black
	2	+ and -	+, black -, white
2-wire dc	2	+	Black White

two-, T for three-, and F for four-conductor cables. The number following this letter denotes the wire's circular mil area in thousands. For example, the cable supplying distribution box symbol 615 (fig. 6-2) is marked (2-38-1)-L-Al-T-g. This marking identifies a three-conductor, 9000-circular mil, 120-volt, ship's service submain lighting cable supplied from panel 2-38-1. Note that you would need the isometric wiring diagram for the main deck and above to follow the complete run of this cable. This print would show lighting main 2(38-l)-lL-A-T-30 supplying a distribution box somewhere on the main deck (or above), and submain cable (2-38-l)-IL-Al-T-9 coming from this distribution box to supply distribution box symbol 615 on the second platform, frame 19 starboard.

Remember, the isometric wiring diagram shows only the general location of the various cables and fixtures. Their exact location is shown on the wiring plan discussed briefly in the next paragraphs.

Wiring Deck Plan

The wiring deck plan is the actual installation diagram for the deck or decks shown and is used chiefly in ship construction. It helps the shipyard electrician lay out his or her work for a number of cables without referring to individual isometric wiring diagrams. The plan includes a bill of material that lists all materials and equipment necessary to complete installation for the deck or decks concerned. Equipment and materials except cables are identified by a symbol number both on the drawing and in the bill of material.

Wiring deck plans are drawn to scale (usually 1/4 inch to the foot), and they show the exact location of all fixtures. One blueprint usually shows from 150 to 200 feet of space on one deck only. Electrical wiring equipment symbols from MIL-STD-15-2 are used to represent fixtures just as they do in the isometric wiring diagram.

Elementary Wiring Diagram

These diagrams show in detail each conductor, terminal, and connection in a circuit. They are used to check for proper connections in circuit or to make the initial hookup.

In interior communication (IC) circuits, for example, the lugs on the wires in each connection are stamped with conductor markings. The elementary wiring diagrams show these conductor markings alongside each conductor and how they connect in the circuit. Elementary wiring diagrams usually do not show the location of connection boxes, panels, and so on; therefore, they are not drawn to any scale.

Electrical System Diagrams

Navy ships have electrical systems that include many types of electrical devices and components. These devices and components may be located in the same section or at various locations throughout the ship. The electrical diagrams and drawings necessary to operate and maintain these systems are found in the ship's electrical blueprints and in drawings and diagrams in NAVSHIPS' and manufacturers' technical manuals.

BLOCK DIAGRAM.—These diagrams of electrical systems show major units of the system in block form. They are used with text material to present a general description of the system and its functions. Figure 6-3 shows a block diagram of the electrical steering system for a large ship. Look at the diagram along with the information in the following paragraphs to understand the function of the overall system.

The steering gear system (fig. 6-3) consists of two similar synchro-controlled electrohydraulic systems; one for each rudder (port and starboard). They are separate systems, but they are normally controlled by the same steering wheel (helm) and they move both port and starboard rudders in unison. Each port and starboard system has two 100 hp main motors driving a variable-stroke pump through reduction gears. Each also has two 5-hp servo pump motors interconnected electrically with the main pump motors so both operate simultaneously. During normal operation, one main pump motor and one servo pump motor are used with the other units on standby. If the normal power supply fails, both port and starboard transfer switchboards may be transferred to an emergency 450-volt supply.

The steering system may be operated from any one of three steering stations located in the pilothouse, at a secondary conn, and on the open bridge. A transmitter selector switch in the IC room is used to assign steering control to any of the three. To transfer steering control from the pilothouse to the open bridge station, the selector switch in the IC room must be in the pilothouse position. Duplicate power and control cables (port and starboard) run from a cable selector in the IC room to port and starboard cable selector switches in the steering gear room. From these switches, power and control cables connect to receiver selector switches. These selector switches allow selection of the appropriate synchro receiver for the system in operation.

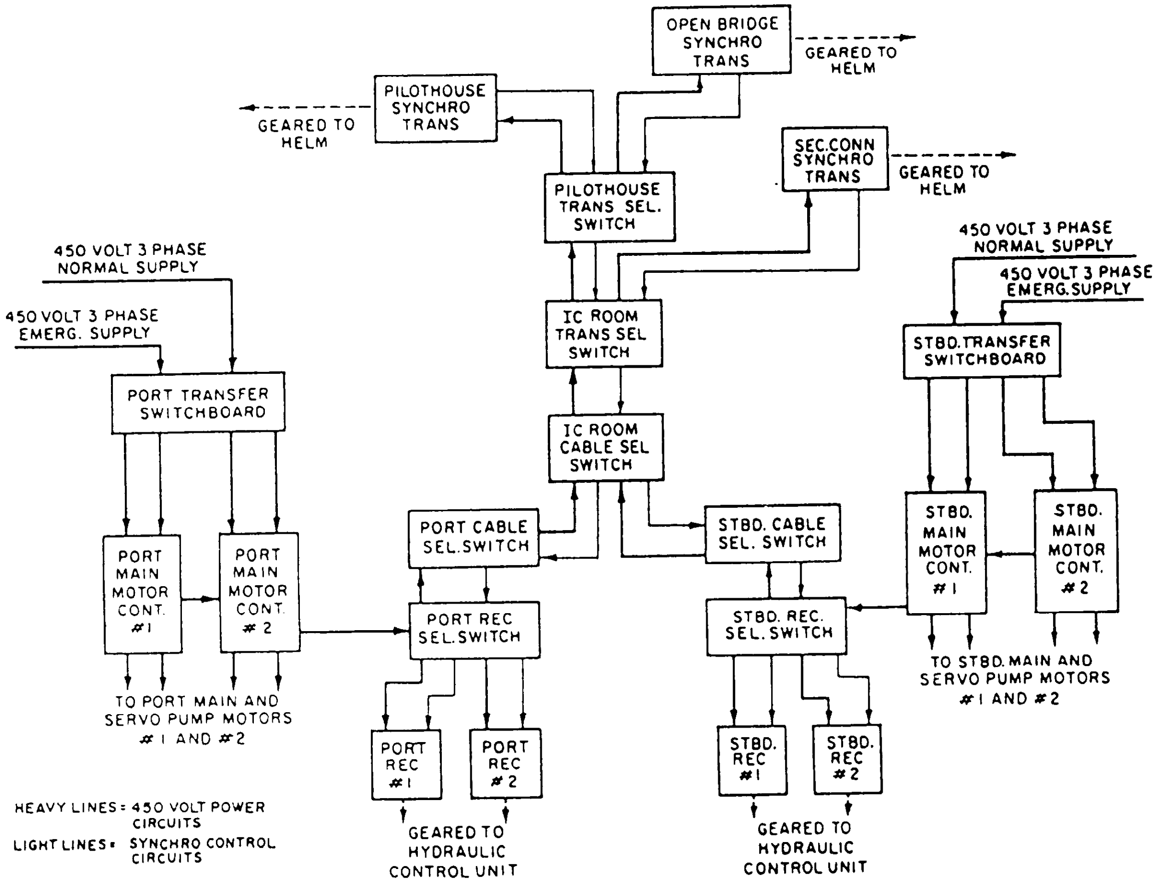


Figure 6-3.—Steering system block diagram.

The following paragraphs explain a normal operating setup for pilothouse steering control of the complete system.

PORT SYSTEM—Main and servo pump motors #2 operating; port receiver selector switch to #2 position, steering gear port cable select switch to the port cable position; IC cable selector switch (port system section) to the port cable position; and IC and pilothouse transmitter selector switches to the pilothouse position.

STARBOARD SYSTEM—Main and servo pump motors #1 operating; starboard receiver selector switch to the #1 position; steering gear starboard cable selector switch to the starboard cable position; and IC cable selector switch (starboard system section) to the starboard cable position.

When the control switches are set up in this manner, the motor and stator leads of the synchro transmitter at the pilothouse steering station are paralleled with the rotor and stator leads of the starboard #1 and port #2 synchro receivers in the steering gear room. 450 volts single phase is applied to the stator leads from main motor controllers #1 and #2. (The synchros have two stator and three rotor leads.) Due to synchro action, the receiver rotors will now follow all movements of the transmitter rotor and thus actuate the hydraulic system to move the rudders in response to the helm.

SINGLE-LINE DIAGRAM.—This type of diagram shows a general description of a system and how it functions. It has more detail than the block diagram; therefore, it requires less supporting text.

Figure 6-4 shows a single-line diagram of the ship's service generator and switchboard connections for a destroyer. It shows the type of ac and dc generators used to supply power for the ship. It also shows in simplified form actual switching arrangements used to parallel the generators, to supply the different power lighting busses, and to energize the casualty power terminals.

EQUIPMENT WIRING DIAGRAM.—Earlier in this chapter, we said a block diagram is useful to show the functional operation of a system. However, to troubleshoot a system, you will need wiring diagrams for the various equipments in the system.

The wiring diagram for a particular piece of electrical equipment shows the relative position of the various components of the equipment and how each individual conductor is connected in the circuit. Some examples are coils, capacitors, resistors, terminal strips, and so on.

Figure 6-5, view A, shows the main motor controller wiring diagram for the steering system shown in figure 6-3. This wiring diagram can be used to troubleshoot, check for proper electrical connections, or completely rewire the controller.

SCHEMATIC DIAGRAM.—The electrical schematic diagram describes the electrical operation of a particular piece of equipment, circuit, or system. It is not drawn to scale and usually does not show the relative positions of the various components. Graphic symbols from ANSI Y32.2 represent all components. Parts and connections are omitted for simplicity if they are not essential to show how the circuit operates. Figure 6-5, view B, shows the schematic diagram for the steering system main motor controller that has the following electrical operation:

Assume 450-volt, 3-phase power is available on lines 1L1, 1L2, and 1L3; and 2L1, 2L2 and 2L3; and the receiver selector is set so that the motors are to idle as standby equipment. Then turn the master switch (MM and SPM push-button station) to the start position to energize coil 3M. Coil 3M will close main line contacts 3M, starting the servo pump motor. When contacts 3M close, auxiliary contacts 3Ma and 3Mb also close. Contacts 3Ma shunt (bypass) the master switch start contacts to maintain power to coil 3M after the master switch is released. When released, the master switch spring returns to the run position, closing the run contacts and opening the start contacts. Turning the switch to the stop position opens the run contacts. Contacts 3Mb energize latching coil CH, closing contacts CH, and energizing coil 1M, which closes main line contacts 1M to start the main pump motor. (Solenoid latch CH prevents contacts 1M from opening or closing due to high-impact shock.)

Before the motors can deliver steering power, the receiver selector switch must be set to the appropriate receiver, closing contacts RSSa and RSSb. Contacts RSSa energize coil 2M, which closes contacts 2M to supply single-phase power to the synchro system. Contacts RSSb shunt the start and 3Ma contacts so that in case of a power failure the motors will restart automatically upon restoration of power.

In case of overload on the main or servo pump motor (excessive current through IOL or 3OL), overload contacts 1OL or 3OL will open, de-energizing coil 3M to open line contacts 3M and stop the servo pump motor. When line contacts 3M open, contacts 3Ma and 3Mb open, deenergizing

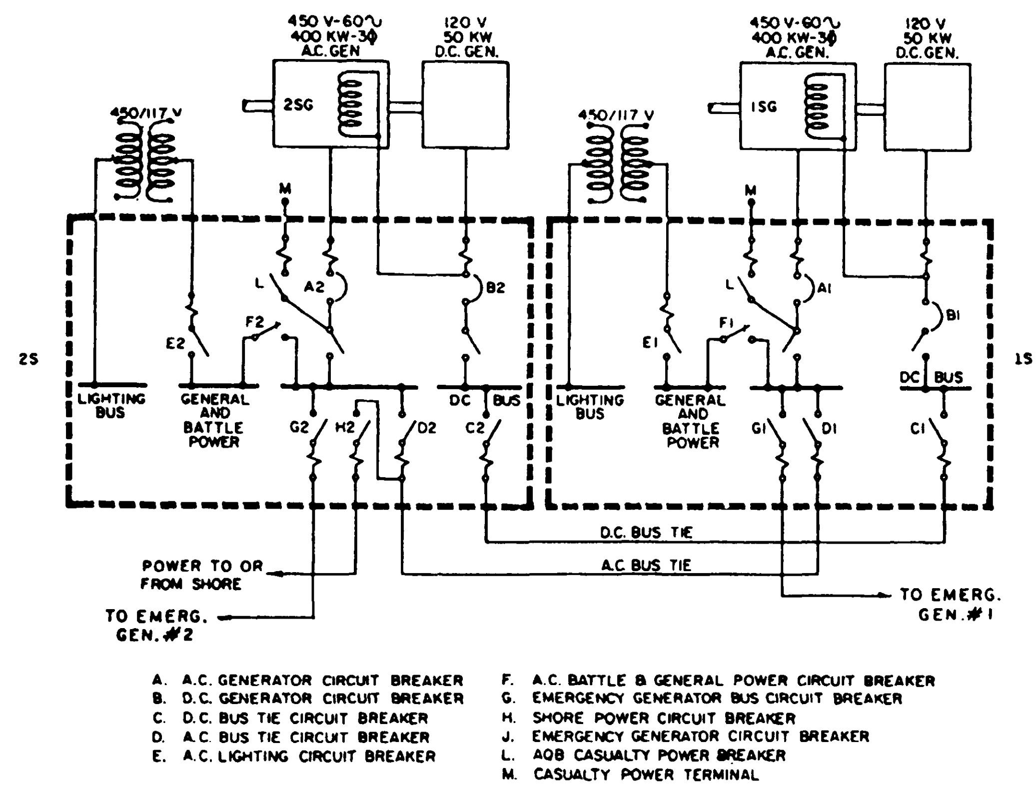


Figure 6-4.—Ship's service generator and switchboard interconnections, single-line diagram.

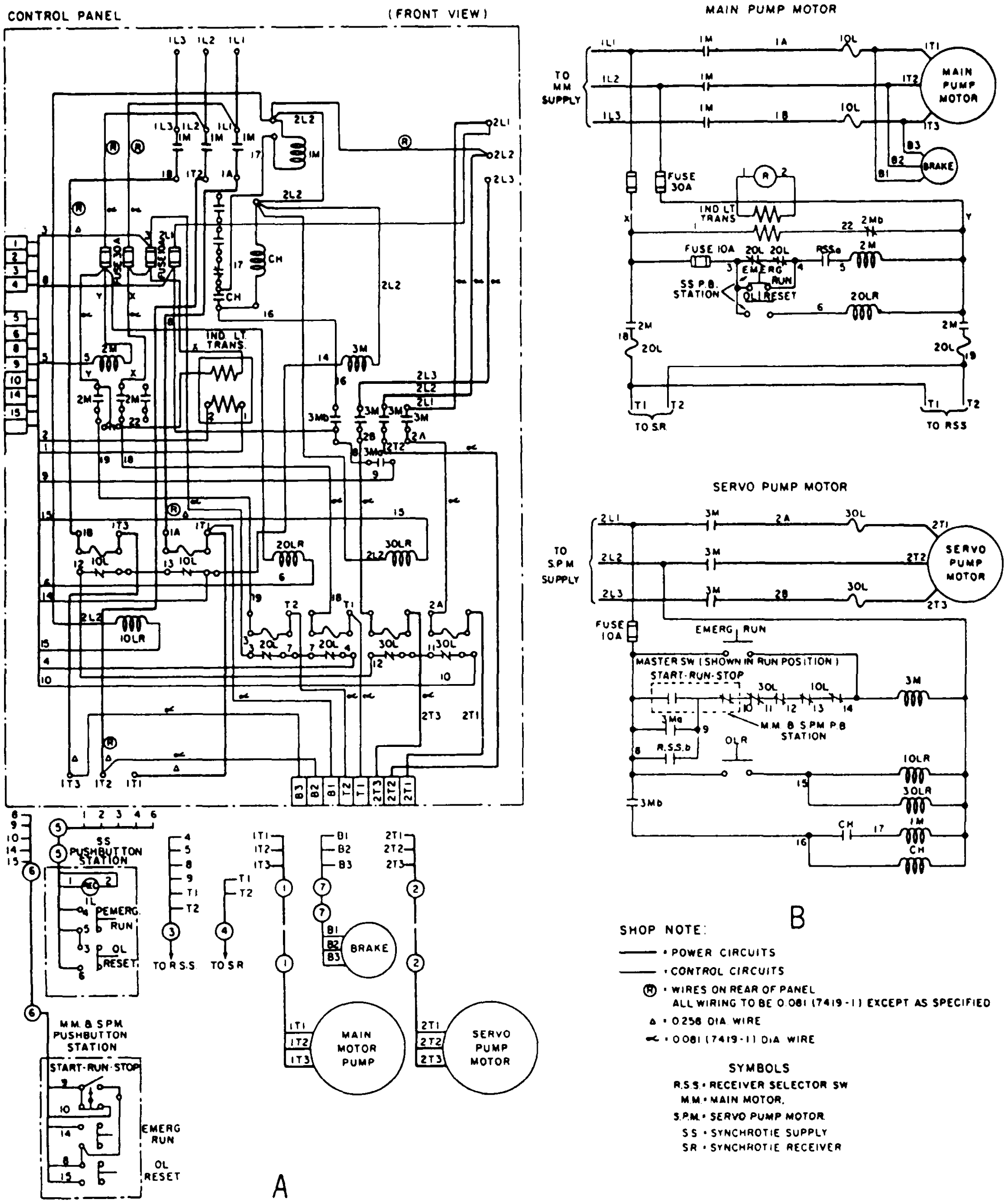


Figure 6-5.—Main motor controller. A. Wiring diagram. B. Schematic.

latching coil CH, and opening contacts CH. The opening of contacts CH de-energizes coil 1M, which opens contacts 1M to stop the main motor. If an overload occurs in the synchro supply circuit (excessive current through 2OL), contacts 2OL will open, deenergizing coil 2M to open contacts 2M. The overloads are reset after tripping by pressing the overload reset buttons. The equipment may be operated in an overloaded condition by pressing the emergency run buttons to shunt the overload contacts.

AIRCRAFT ELECTRICAL PRINTS

Aircraft electrical prints include schematic diagrams and wiring diagrams. Schematic diagrams show electrical operations. They are drawn in the same manner and use the same graphic symbols from ANSI Y32.2 as shipboard electrical schematics.

Aircraft electrical wiring diagrams show detailed circuit information on all electrical systems. A master wiring diagram is a single diagram that shows all the wiring in an aircraft. In most cases these would be so large as to be impractical; therefore, they are broken down into logical sections such as the dc power system, the ac power system, and the aircraft lighting system.

Diagrams of major circuits generally include an isometric shadow outline of the aircraft showing the location of items of equipment and the routing of interconnecting cables, as shown in figure 6-6, view

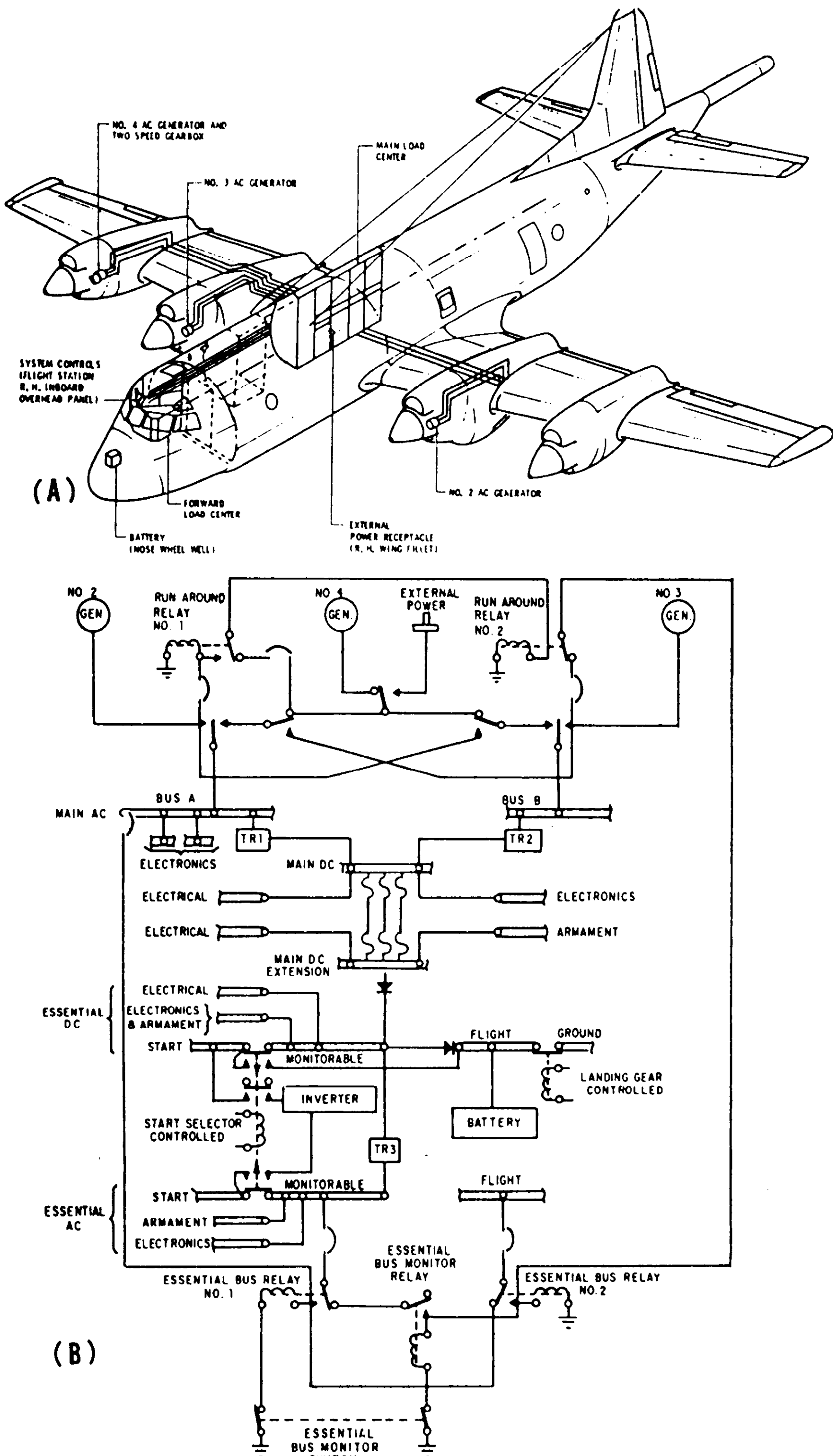


Figure 6-6.—Electrical power distribution in P-3A aircraft.

A. This diagram is similar to a shipboard isometric wiring diagram.

The simplified wiring diagram (fig. 6-6, view B) may be further broken down into various circuit wiring diagrams showing in detail how each component is connected into the system. Circuit wiring diagrams show equipment part numbers, wire numbers, and all terminal strips and plugs just as they do on shipboard wiring diagrams.

Aircraft Wire Identification Coding

All aircraft wiring is identified on the wiring diagrams exactly as marked in the aircraft. Each wire is coded by a combination of letters and numbers imprinted at prescribed intervals along the run. You need to look at figure 6-7 as you read the following paragraphs.

The unit number shown dashed (fig. 6-7) is used only in those cases where more that one identical unit is installed in an identical manner in the same aircraft. The wiring for the first such unit would bear the prefix 1, the second unit the prefix 2, and so on. The rest of the designation remains the same in both units.

The circuit function letter identifies the basic function of the unit concerned according to the codes shown in figure 6-8. Note the dashed L after the circuit function R in figure 6-7. On R, S, and T wiring, this letter designates a further breakdown of the circuit.

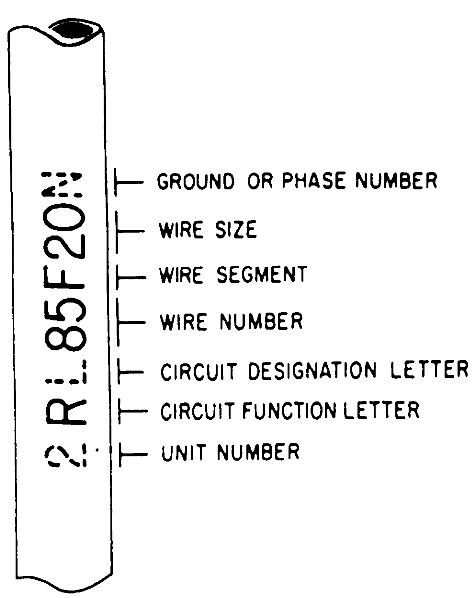


Figure 6-7.—Aircrafl wire identification.

Circuit function letter	Circuits
A	Armament
B	Photographic
C	Control surface
D	Instrument
E	Engine instrument
F	Flight instrument
G	Landing gear
H	Heating, ventilating, and deicing
J	Ignition
K	Engine control
L	Lighting
M	Miscellaneous
P	DC power — Wiring in the dc power or power control system will be identified by the circuit function letter P.
Q	Fuel and oil
R	Radio (navigation and communication) RN-Navigation RP-Intercommunications RZ-Interphone, headphone
S	Radar SA-Altimeter SN-Navigation SQ-Track SR-Recorder SS-Search
T	Special electronic TE-Countermeasures TN-Navigation TR-Rece ivers TX-Television transmitters TZ-Computer
V	DC power and dc control wires for ac systems will be identified by the circuit function letter V.
W	Warning and emergency
X	AC power Wiring in the ac power system will be identified by the circuit function letter X.
Y	Armament special systems

Figure 6-8.—Aircraft wiring, circuit function code.

ELECTRONICS PRINTS

Electronics prints are similar to electrical prints, but they are usually more difficult to read because they represent more complex circuitry and systems. This part of the chapter discusses common types of shipboard and aircraft electronic prints and basic logic diagrams.

SHIPBOARD ELECTRONICS PRINTS

Shipboard electronics prints include isometric wiring diagrams that show the general location of electronic units and the interconnecting cable runs, elementary wiring diagrams that show how each individual cable is connected, block diagrams, schematic diagrams, and interconnection diagrams.

Cables that supply power to electronic equipment are tagged as explained in the electrical prints part of this chapter. However, cables between units of electronic equipment are tagged with electronic designations. Figure 6-9 shows a partial listing of these designations. The complete designation list (contained in NAVSHIPS 0967-000-0140), breaks down all system designation as shown for radar in figure 6-9.

Cables between electronic units are tagged to show the system with which the cable is associated and the individual cable number. For example, in the cable marking R-ES4, the R identifies an electronic cable, ES identifies the cable as a surface search radar cable, and 4 identifies the cable number. If a circuit has two or more cables with identical designations, a circuit differentiating number is placed before the R, such as 1R-ES4, 2R-ES4, and so on.

Block Diagrams

Block diagrams describe the functional operation of an electronics system in the same way they do in electrical systems. In addition, some electronics block diagrams provide information useful in trouble-shooting, which will be discussed later.

A simplified block diagram is usually shown first, followed by a more detailed block diagram. Figure 6-10 shows a simplified block diagram of a shipboard tactical air navigation (TACAN) system.

Circuit or system designation	Circuit or system title
R-A	Meteorological
R-B	Beacons
R-C	Countermeasures
R-D	Data
R-E	Radar
R-EA	Air search radar
R-EC	Carrier controlled approach radar
R-ED	Radar identification
R-EE	Air search with height determining capability
R-EF	Height determining radar
R-EG	Guided missile tracking radar
R-EI	Instrumentation radar
R-EM	Mortar locator radar
R-ER	Radar remote indicators
R-ES	Surface search radar
R-ET	Radar trainer
R-EW	Aircraft early warning radar
R-EZ	Three-coordinate radar
R-F	Weapon control radar
R-G	Electronic guidance remote control or remote telemetering
R-H	CW passive tracking
R-I	IFF equipment
R-K	Precision timing
R-L	Automatic vectoring
R-M	Missile support
R-N	Infrared equipment
R-P	Special purpose
R-R	Radio communication
R-S	Sonar
R-T	Television

Figure 6-9.—Electronics circuit or system designations.

The TACAN system is an electronic air navigation system that provides a properly equipped aircraft with bearing and distance from a shipboard or ground radio beacon selected by the pilot. The system is made up of a radio beacon (consisting of the receiver-transmitter group, the antenna group, and the power supply assembly) and the radio set in the aircraft.

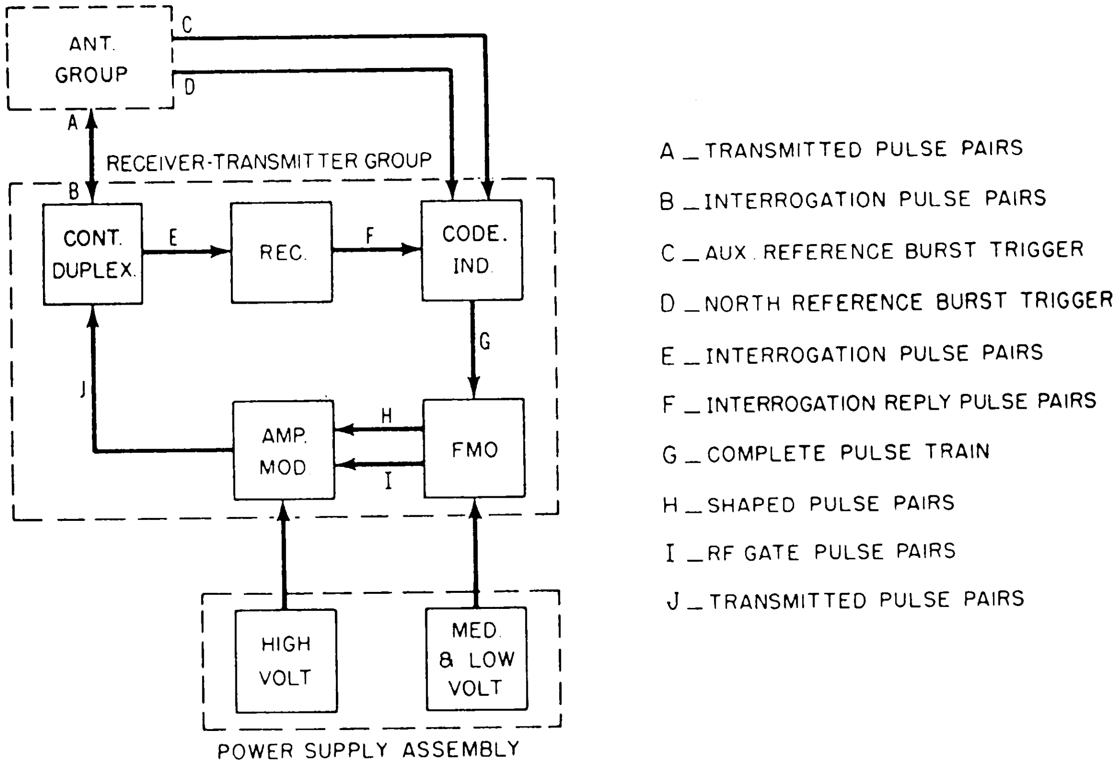


Figure 6-10.—Shipboard TACAN system, simplified block diagram.

Figure 6-11 shows how the code indicator section would appear in a detailed block diagram for the TACAN system shown in figure 6-10. Note that this diagram shows the shape and amplitude of the wave forms at various points and the location of test points. Tube elements and pin numbers are also identified. For example, the interrogation reply pulse (top left comer of fig. 6-11) is applied to the grid (pin 7) of V604B, and the output from the cathode (pin 8) of V604B is applied to the grid (pin 2) of V611. Therefore, this kind of block diagram is sometimes called a servicing block diagram because it can be used to troubleshoot as well as identify function operations. Block diagrams that break down the simplified diagram into enough detail to show a fairly detailed picture of functional operation, but do not include wave forms, test points, and so on, are usually called functional block diagrams.

Graphic electrical and electronic symbols are frequently used in functional and detailed block diagrams of electronic systems to present a better picture of how the system functions. Note the graphic symbol for the single-pole, two-position switch S603 at the bottom left comer in figure 6-11. Figure 6-12 shows other examples of graphic symbols in a block diagram.

Detailed block diagrams of the type shown in figure 6-12 can be used to isolate a trouble to a particular assembly or subassembly. However, schematic diagrams are required to check the individual circuits and parts.

Schematic Diagrams

Electronic schematic diagrams use graphic symbols from ANSI Y32.2 for all parts, such as tubes, transistors, capacitors, and inductors. Appendix III in this textbook shows common electronic symbols from this standard. Simplified schematic diagrams are used to show how a particular circuit operates electronically. However, detailed schematic diagrams are necessary for trouble-shooting.

Figure 6-13 shows a section of the detailed schematic diagram of the coder indicator show in figure 6-11. Some of the components in figure 6-13 are not numbered. In an actual detailed schematic, however, all components, such as resistors and capacitors, are identified by a letter and a number and their values are given. All tubes and transistors are identified by a letter and a number and also by type. Input signals are shown entering on the left (fig. 6-13) and signal flow is from left to right, which is the general rule for schematic diagrams.

In the block diagram in figure 6-11, the north reference burst signal is shown applied to the pin 7 grid of V601B. The pin 6 plate output of V601B is fed to the pin 7 grid of V602, and the pin 3 cathode output of V602

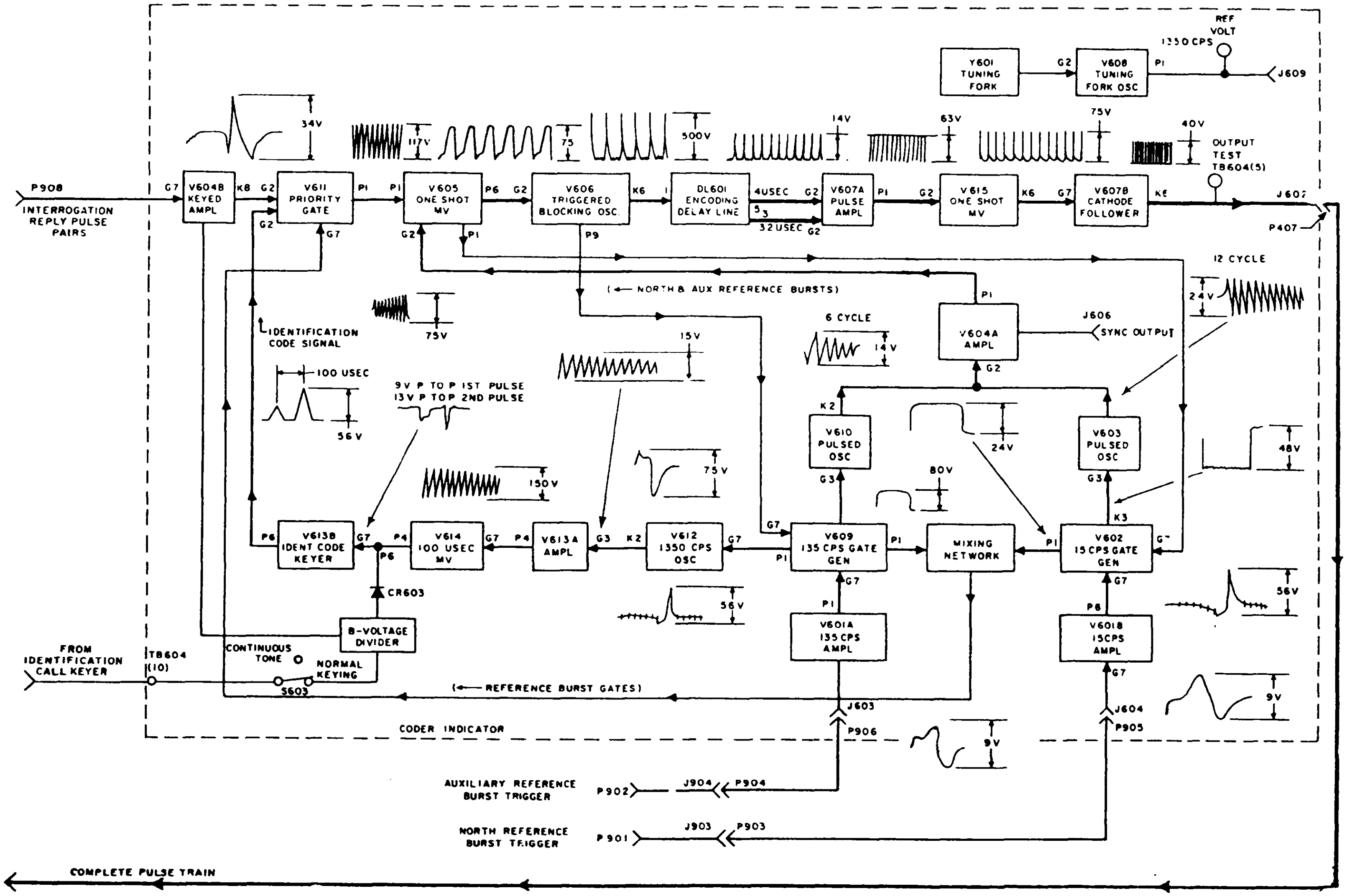


Figure 6-11.—Coder indicator, detail block diagram.

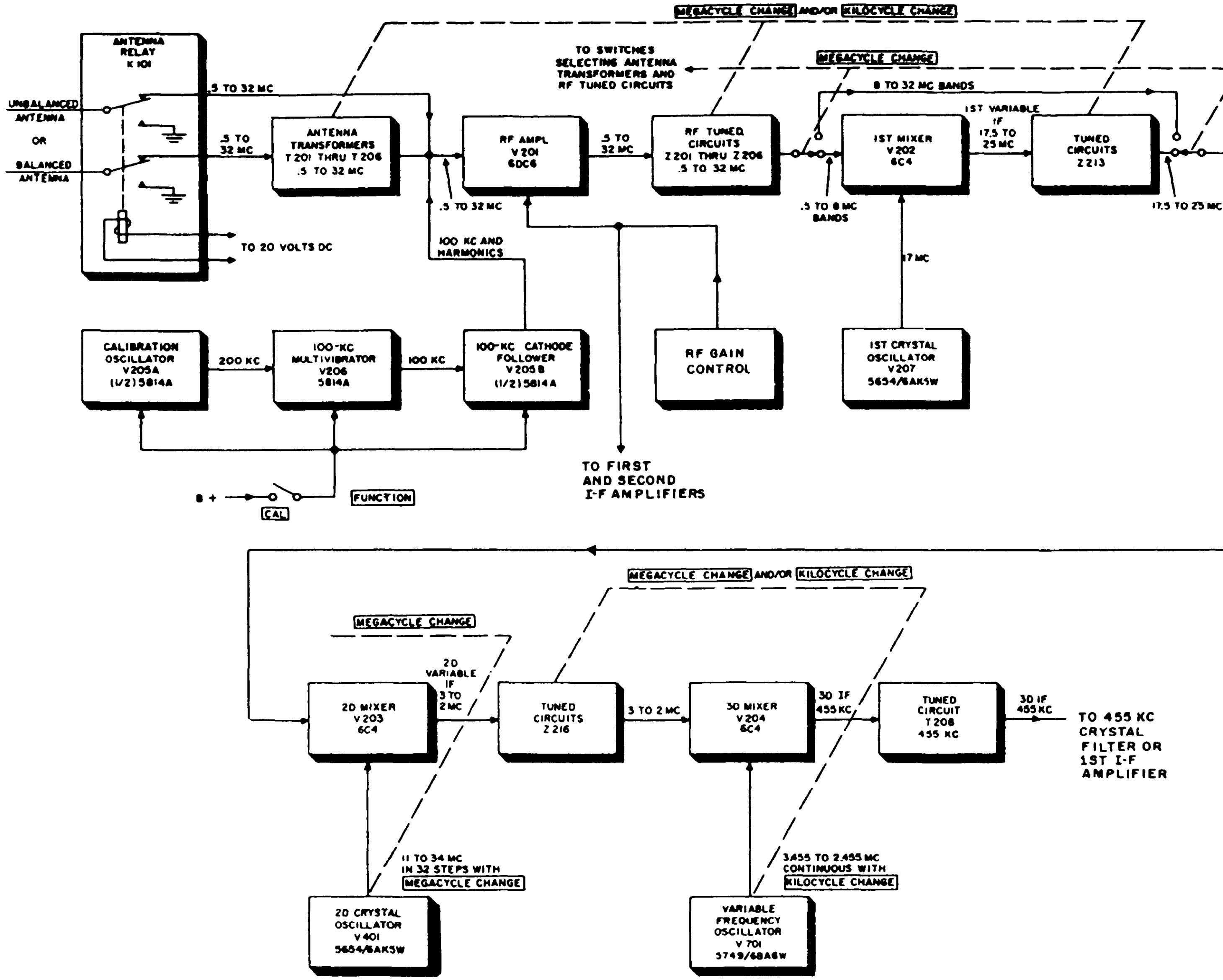


Figure 6-12.—Section of radio receiver R-390A/URR, functional block diagram.

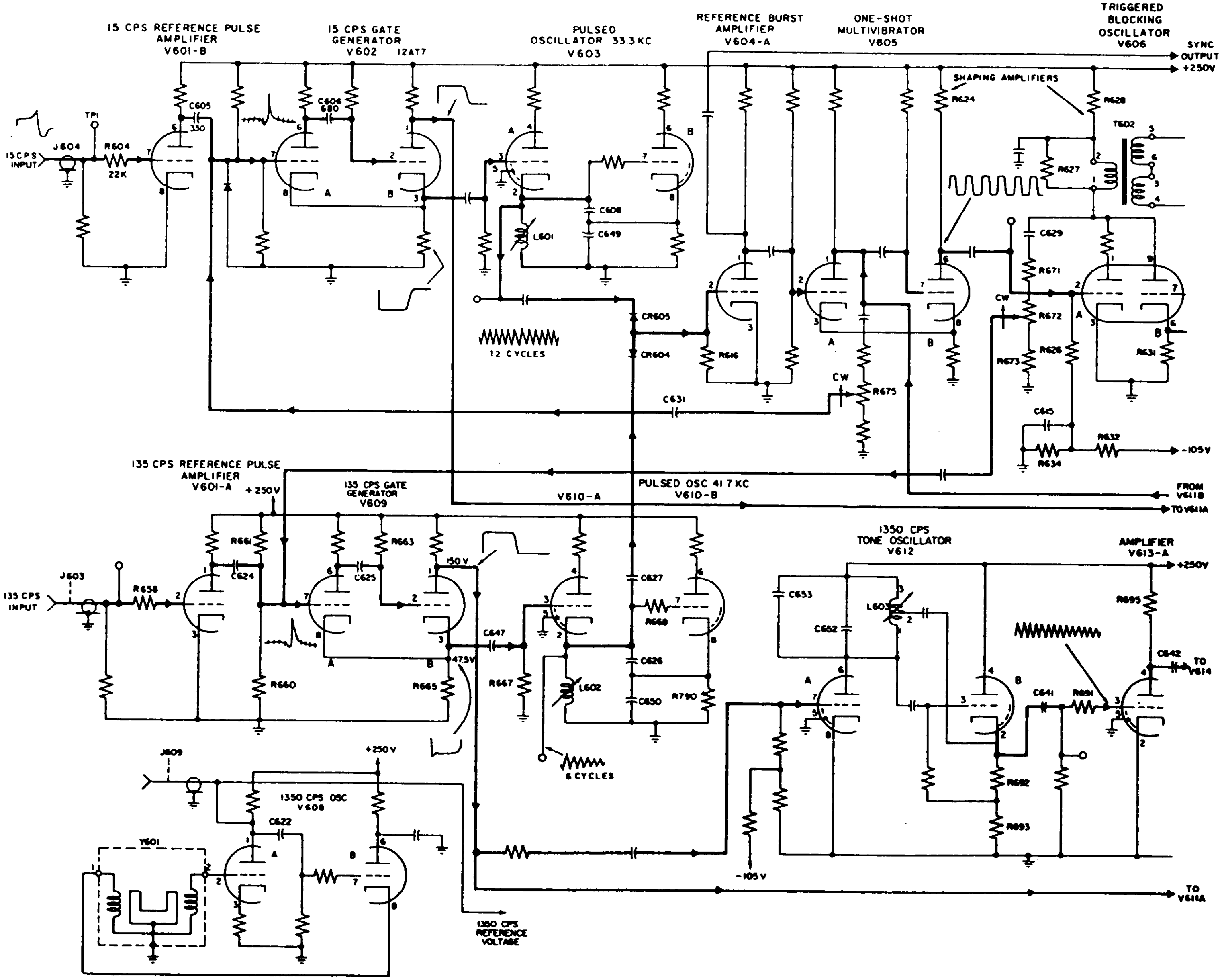


Figure 6-13.—Section of coder indicator, detailedd schematic diagram.

is applied to the pin 3 grid of V603, and so on. In addition, the schematic diagram in figure 6-13 shows that the north reference burst signal is fed through 22K (22,000 ohms) resistor R604 grid 7 and that the plate output of V601B is coupled through capacitor C605 (a 330 picofared capacitor) to the grid of section A of V602, twin-triode type 12AT7 tube. Therefore, the detailed schematic diagram shows detailed information about circuits and parts and must be used in conjunction with the detailed block diagram to effectively troubleshoot a system.

Wiring Diagrams

Electronic equipment wiring diagrams show the relative positions of all equipment parts and all electrical connections. All terminals, wires, tube sockets, resistors, capacitors, and so on are shown as they appear in the actual equipment. Figure 6-14 shows a sample wiring diagram. Designations 1A1, 1A1A1, and 1A1A2 are reference designations and will be discussed later.

Figure 6-15 shows the basic wiring color code for electronic equipment.

Reference Designations

A reference designation is a combination of letters and numbers used to identify the various parts and components on electronic drawings, diagrams, parts lists, and so on. The prints you work with will have one of two systems of reference designations. The old one is called a block numbering system and is no longer in use. The current one is called a unit numbering system. We will discuss both in the following paragraphs.

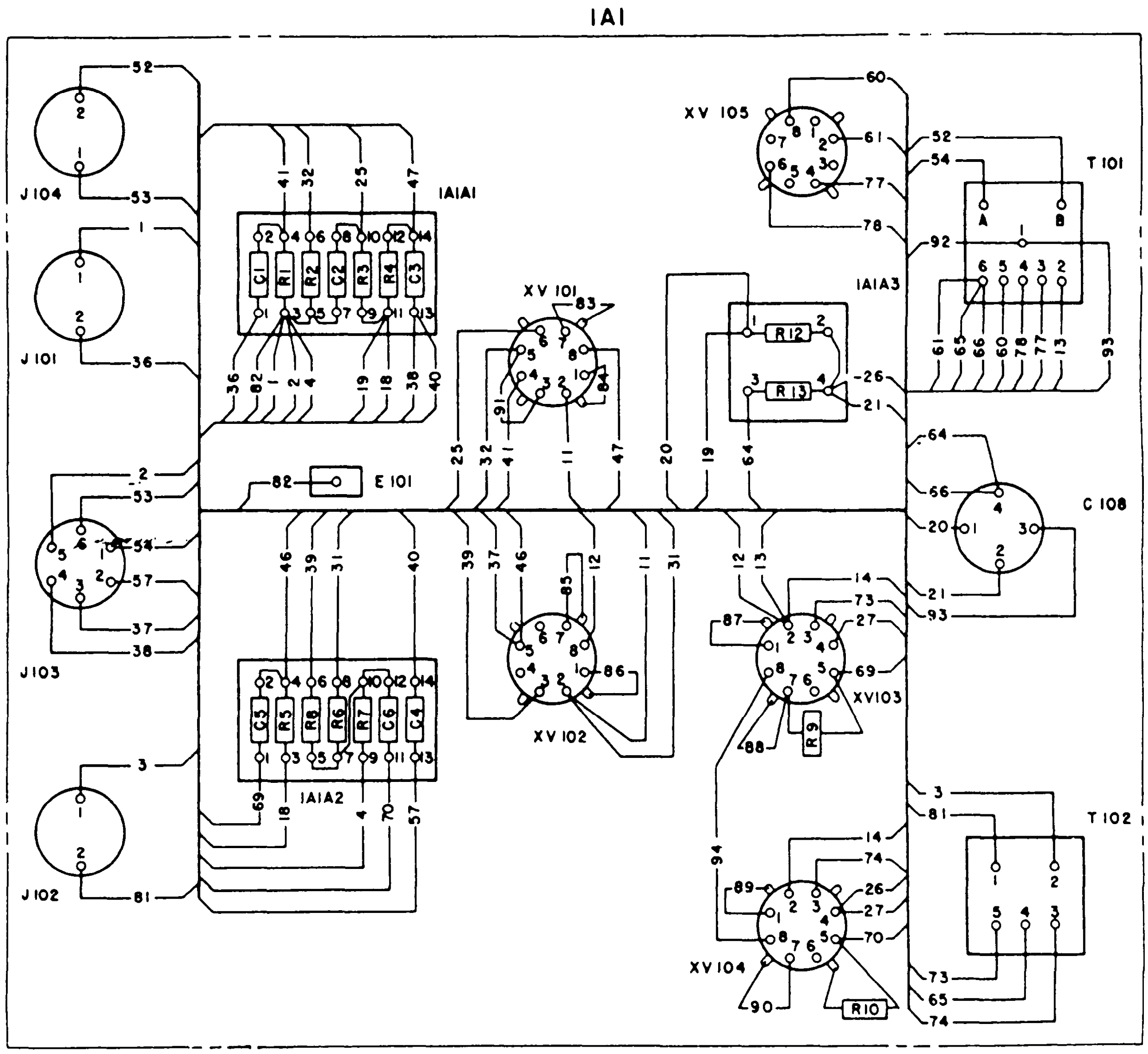


Figure 6-14.—Sample wiring diagram.

CIRCUIT	COLOR
Grounds, grounded elements, and returns	Black
Heaters or filaments, off ground	Brown
Power supply, B plus	Red
Screen grids	Orange
Cathodes	Yellow
Control grids	Green
Plates	Blue
Power supply, minus	Violet (purple)
AC power lines	Gray
Miscellaneous, above or below ground returns, AVC, etc.	White

Figure 6-15.—Wiring color code for electronic equipment.

BLOCK NUMBERING SYSTEM.—Parts designations in figures 6-11, 6-12, and 6-13 were made according to the block numbering system, which is no longer in use. In that system, a letter identifies the class to which a part belongs, such as R for resistor, C for capacitor, V for electron tube, and so on. A number identifies the specific part and in which unit of the system the part is located. Parts within each class in the first unit of a system are numbered consecutively from 1 through 199, parts in the second unit from 201 through 299, and so on.

UNIT NUMBERING SYSTEM.—In this currently used reference designation system, electronic systems are broken into sets, units, assemblies, subassemblies, and parts. A system is defined as two or more sets and other assemblies, subassemblies, and parts necessary to perform an operational function or functions. A set (fig. 6-16) is defined as one or more units

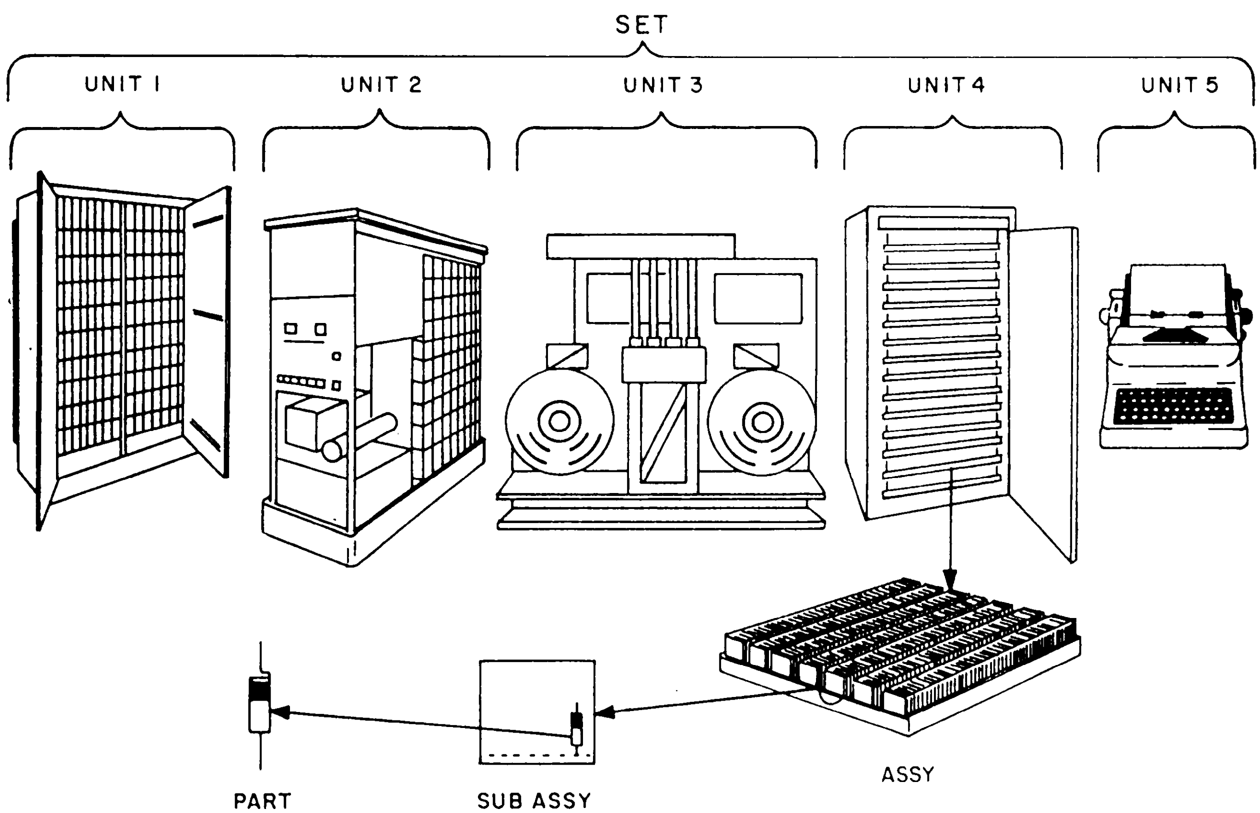


Figure 6-16.—A five-unit set.

and the necessary assemblies, subassemblies, and parts connected or associated together to perform an operational function.

Reference designations are assigned beginning with the unit and continuing down to the lowest level (parts). Units are assigned a number beginning with 1 and continuing with consecutive numbers for all units of the set. This number is the complete reference designation for the unit. If there is only one unit, the unit number is omitted.

Assemblies and subassemblies are assigned reference designations consisting of the unit number that identifies the unit of which the assembly or subassembly is a part, the letter *A* indicating an assembly or subassembly, and a number identifying the specific assembly or subassembly as shown in figure 6-17.

Parts are assigned reference designations that consist of the unit and assembly or subassembly designation, plus a letter or letters identifying the class to which the part belongs (as in the block numbering system), and a number identifying the specific part.

For each additional subassembly, an additional letter *A* and number are added to the part reference designation. For example, if the resistor shown in figure 6-16 is the number 1 resistor in the subassembly, its complete reference designation would be 4A13A5AlRl. This number identifies the number 1 resistor on the number card of rack number 5 in assembly 13 of unit 4. On electronic diagrams, the usual procedure is to use partial (abbreviated) reference designations. In this procedure, only the letter and number identifying the part is shown on the part itself, while the reference designation prefix appears at some other place on the diagram as shown in figure 6-14. For the complete reference designation, the designation prefix precedes the partial designation.

Interconnection Diagrams

Interconnection diagrams show the cabling between electronic units and how the units are interconnected (fig. 6-18). All terminal boards are assigned reference designations according to the unit numbering method described previously. Individual terminals on the terminal boards are assigned letters and/or numbers according to *Standard Terminal Designations for Electronic Equipment,* NAVSHIPS 0967-146-0010.

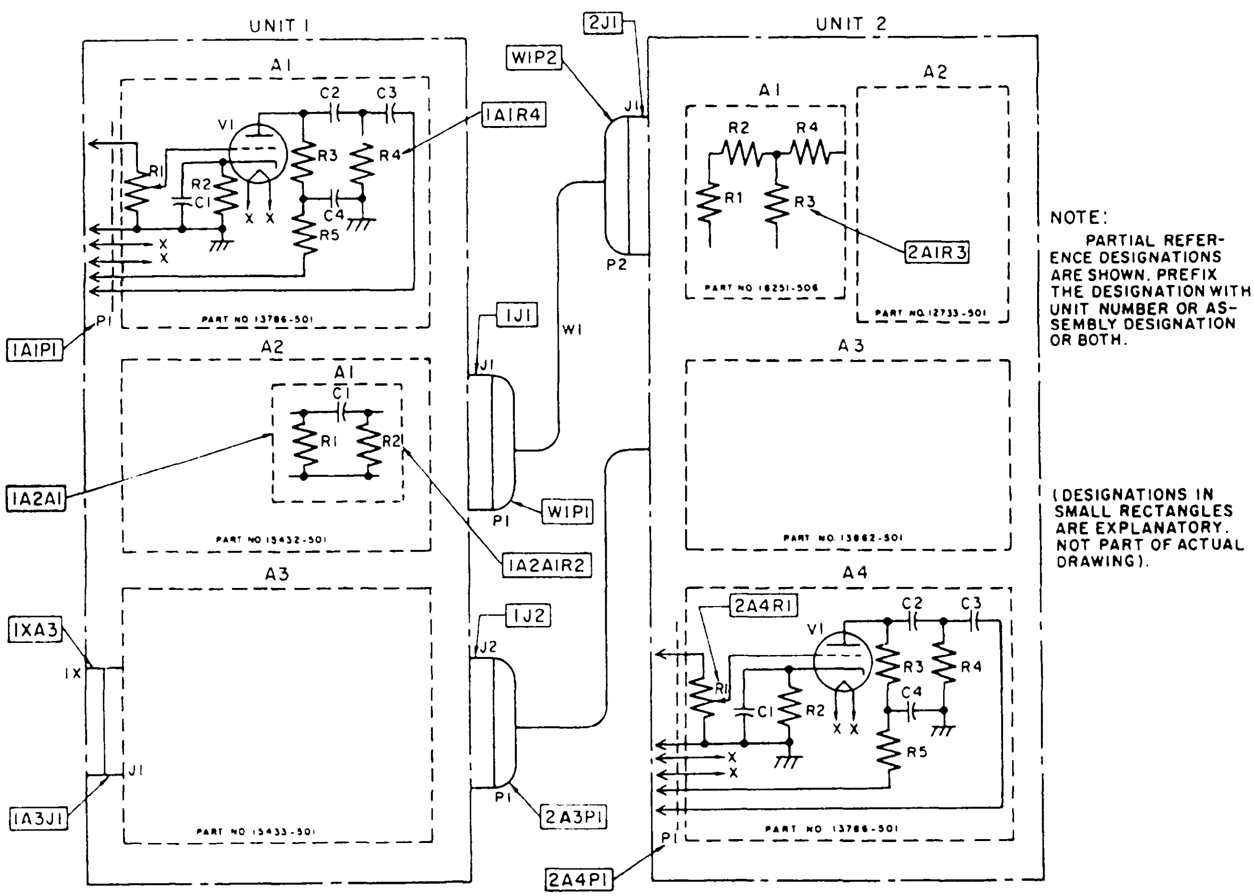


Figure 6-17.—Application of reference designations using unit numbering methods.

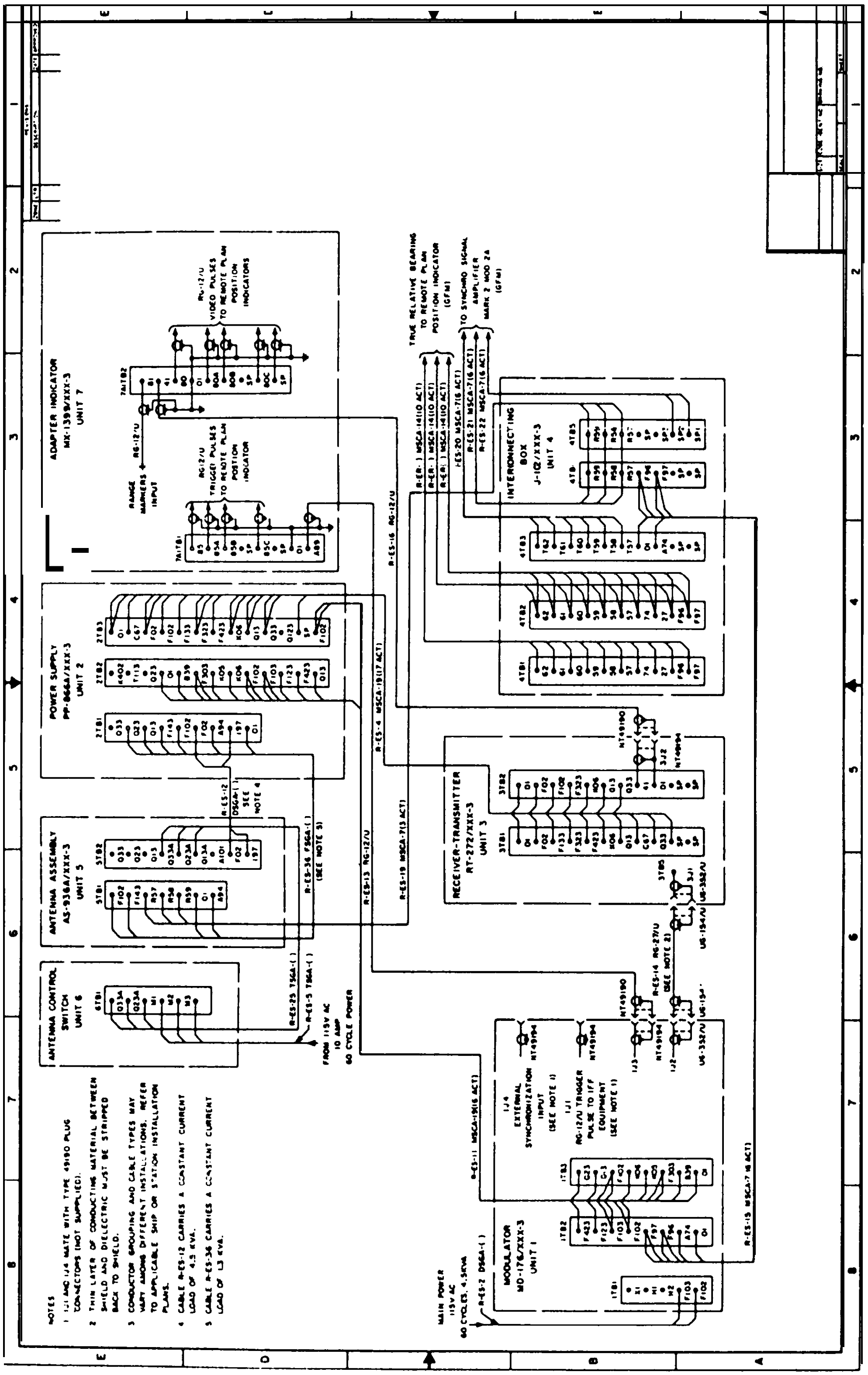


Figure 6-18.—Sample interconnection diagram.

The cables between the various units are tagged showing the circuit or system designation and the number as stated earlier. In addition, the interconnection diagram also shows the type of cable used. For example, look at cable R-ES11 between the power supply unit and the modulator unit in figure 6-18. R-ES11 identifies the cable as the number 11 cable of a surface search radar system. The MSCA-19 (16 ACT) is the designation for a multiconductor ship control armored cable with 19 conductors, 16 active and 3 spares.

Individual conductors connecting to terminal boards are tagged with a vinyl sleeving called spaghetti that shows the terminal board and terminal to which the outer end of the conductor is connected. For example, the ends of the conductor in cable R-ES11 connected to terminals F423 on ITB2 and 2TB2 would be tagged as shown in figure 6-19.

AIRCRAFT ELECTRONICS PRINTS

Aircraft electronics prints include isometric wiring diagrams of the electronics systems showing the locations of the units of the systems and the interconnecting wiring. Both simplified and detailed block and schematic diagrams are used. They show operation and

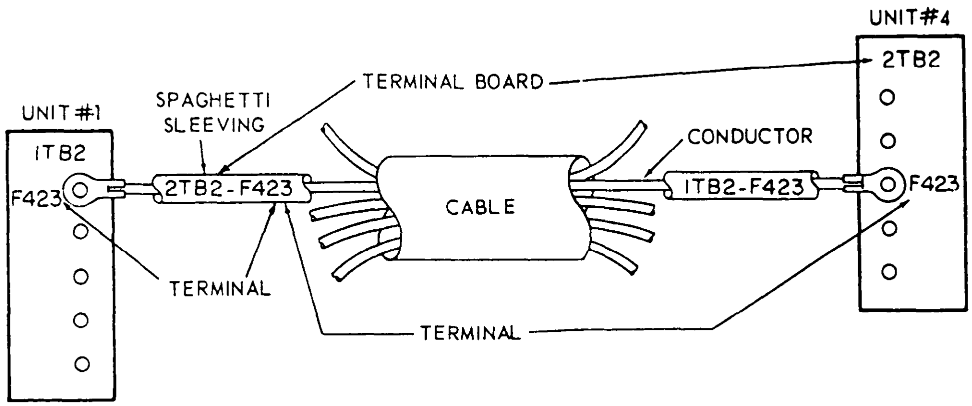


Figure 6-19.—Conductor markings.

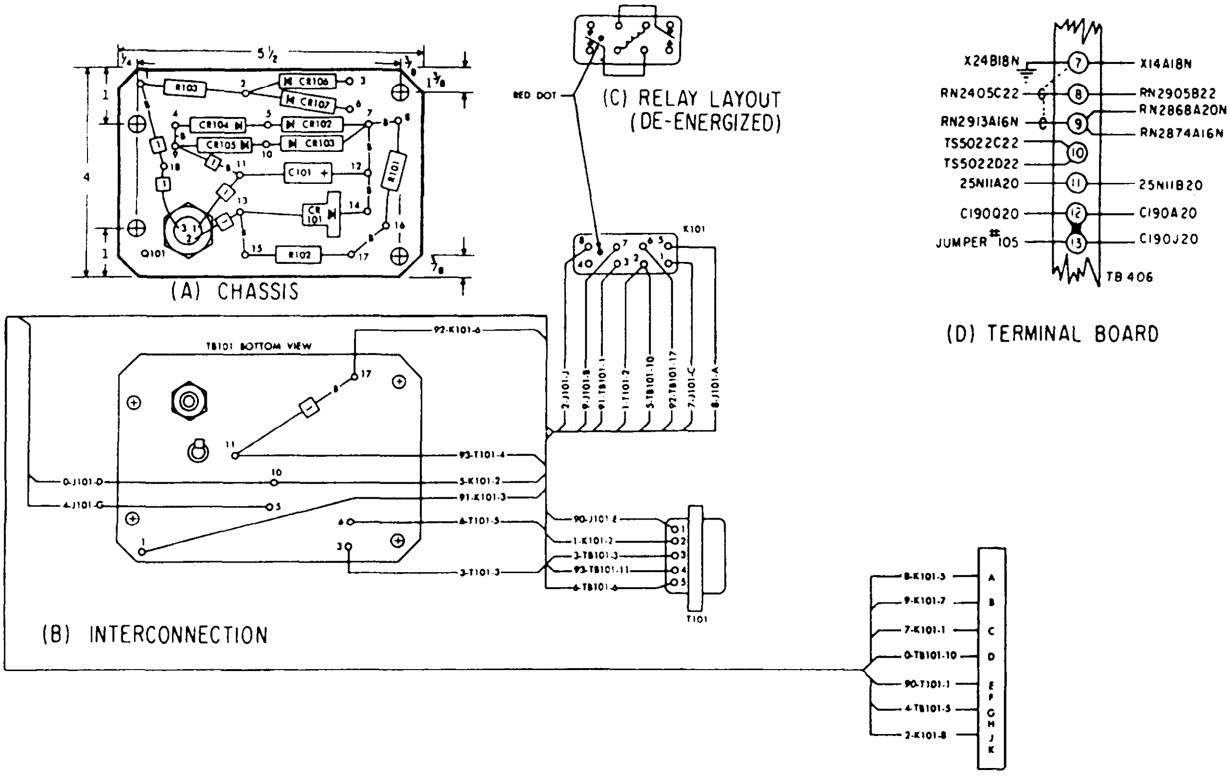


Figure 6-20.—Aircraft wiring diagram.

serve as information for maintenance and repair in the same way as those in shipboard electronics systems. Detailed block diagrams of complicated systems that contain details of signal paths, wave shapes, and so on are usually called signal flow diagrams.

Wiring Diagrams

Aircraft electronic wiring diagrams fall into two basic classes: chassis wiring diagrams and interconnecting diagrams. There are many variations of each class, depending on the application.

Figure 6-20, view A, shows an example of one type of chassis wiring diagram. This diagram shows the physical layout of the unit and all component parts and interconnecting tie points. Each indicated part is identified by a reference designation number that helps you use the illustrated parts breakdown (IPB) to determine value and other data. (Wiring diagrams normally do not show the values of resistors, capacitors, or other components.) Since this specific diagram shows physical layout and dimensioning details for mounting holes, it could be used as an assembly drawing and as an installation drawing.

Figure 6-20, view B, shows the reverse side of the same mounting board, together with the wiring interconnections to other components. It does not show the actual positioning of circuit components, and it shows wire bundles as single lines with the separate wires entering at an angle.

The wire identification coding on this diagram consists of a three-part designation. The first part is a number representing the color code of the wire according to Military Specification MIL-W-76B. (Many other chassis wiring diagrams designate color coding by abbreviation of the actual colors.) The second part is the reference part designation number of the item to which the wire is connected, and the last part is the designation of the terminal to which connection is made.

Figure 6-20, view C, is not a wiring diagram, but it illustrates a method commonly used to show some functional aspect of sealed or special components.

Figure 6-20, view D, illustrates several methods used to show connections at terminal strips, as discussed earlier.

Electromechanical Drawings

Electromechanical devices such as synchros, gyros, accelerometers, autotune systems, an analog computing elements are quite common in avionics systems. You need more than an electrical or electronic drawing to understand these systems adequately; therefore, we use a combination drawing called an electromechanical drawing. These drawings are usually simplified both electrically and mechanically, and show only those items essential to the operation. Figure 6-21 shows an example of one type of electromechanical drawing.

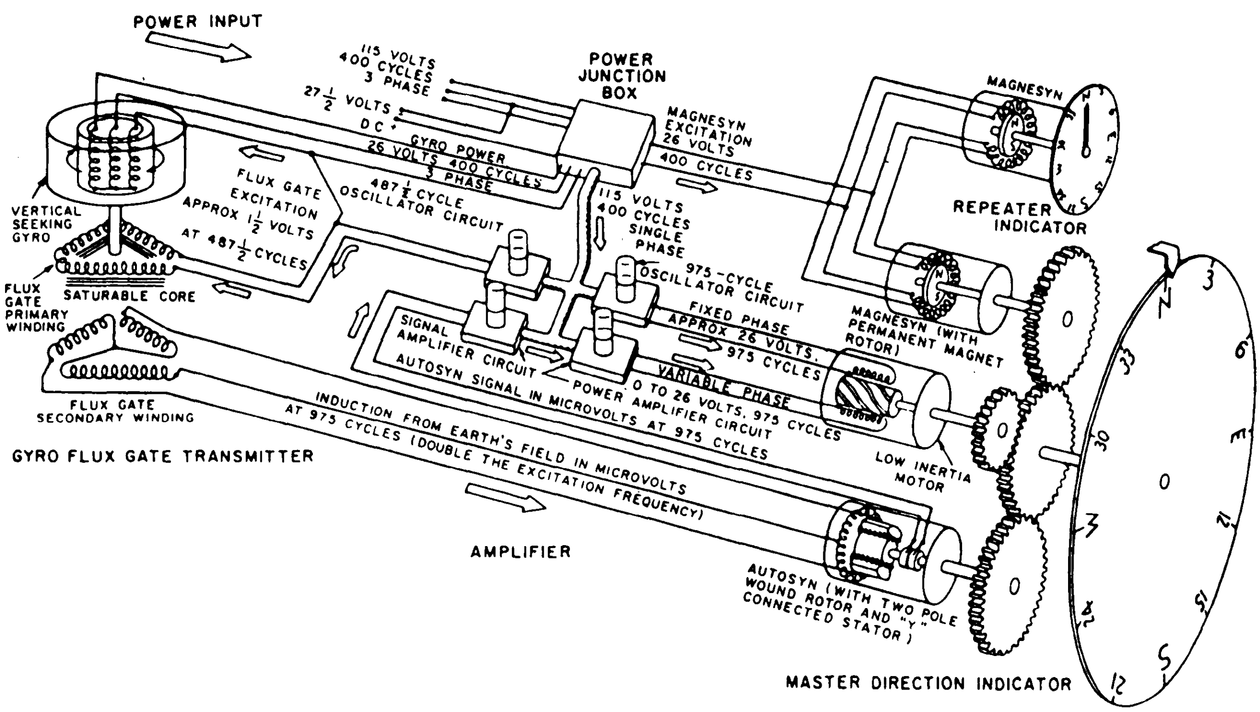


Figure 6-21.—Aircraft gyro fluxgate compass, electromechanical drawing.

LOGIC DIAGRAMS

Logic diagrams are used in the operation and maintenance of digital computers. Graphic symbols from ANSI Y32.14 are used in these diagrams.

Computer Logic

Digital computers are used to make logic decisions about matters that can be decided logically. Some examples are when to perform an operation, what operation to perform, and which of several methods to follow. Digital computers never apply reason and think out an answer. They operate entirely on instructions prepared by someone who has done the thinking and reduced the problem to a point where logical decisions can deliver the correct answer. The rules for the equations and manipulations used by a computer often differ from the familiar rules and procedures of everyday mathematics.

People use many logical truths in everyday life without realizing it. Most of the simple logical patterns are distinguished by words such as *and, or, not, if, else,* and *then.* Once the verbal reasoning process has been completed and results put into statements, the basic laws of logic can be used to evaluate the process. Although simple logic operations can be performed by manipulating verbal statements, the structure of more complex relationships can more usefully be represented by symbols. Thus, the operations are expressed in what is known as symbolic logic.

The symbolic logic operations used in digital computers are based on the investigations of George Boole, and the resulting algebraic system is called Boolean algebra.

The objective of using Boolean algebra in digital computer study is to determine the truth value of the combination of two or more statements. Since Boolean algebra is based upon elements having two possible stable states, it is quite useful in representing switching circuits. A switching circuit can be in only one of two possible stable states at any given time; open or closed. These two states may be represented as 0 and 1 respectively. As the binary number system consists of only the symbols 0 and 1, we can see these symbols with Boolean algebra.

In the mathematics with which you are familiar, there are four basic operations—addition, subtraction, multiplication, and division. Boolean algebra uses three basic operations—AND, OR, and NOT. If these words do not sound mathematical, it is only because logic began with words, and not until much later was it translated into mathematical terms. The basic operations are represented in logical equations by the symbols in figure 6-22.

The addition symbol (+) identifies the OR operation. The multiplication symbol or dot (•) identifies the AND operation, and you may also use parentheses and other multiplication signs.

Logic Operations

Figure 6-23 shows the three basic logic operations (AND, OR, and NOT) and four of the simpler combinations of the three (NOR, NAND, INHIBIT, and EXCLUSIVE OR). For each operation, the figure also shows a representative switching circuit, a truth table, and a block diagram. In some instances, it shows more than one variation to illustrate some specific point in the discussion of a particular operation. In all cases, a 1 at the input means the presence of a signal corresponding to *switch closed,* and a 0 represents the absence of a signal, or *switch open.* In all outputs, a 1 represents a signal across the load, a 0 means no signal.

For the AND operation, every input line must have a signal present to produce an output. For the OR operation, an output is produced whenever a signal is present at any input. To produce a no-output condition, every input must be in a no-signal state.

In the NOT operation, an input signal produces no output, while a no-signal input state produces an output signal. (Note the block diagrams representing the NOT circuit in the figure.) The triangle is the symbol for an amplifier, and the small circle is the symbol for the NOT function. The circle is used to indicate the low-level side of the inversion circuit.

Operation	Meaning
A•B	A AND B
A+B	A OR B
A	A NOT or NOT A
(A + B) (C)	A OR B, AND C
AB+C	A AND B, OR C
A•B	A NOT, AND B

Figure 6-22.—Logic symbols.

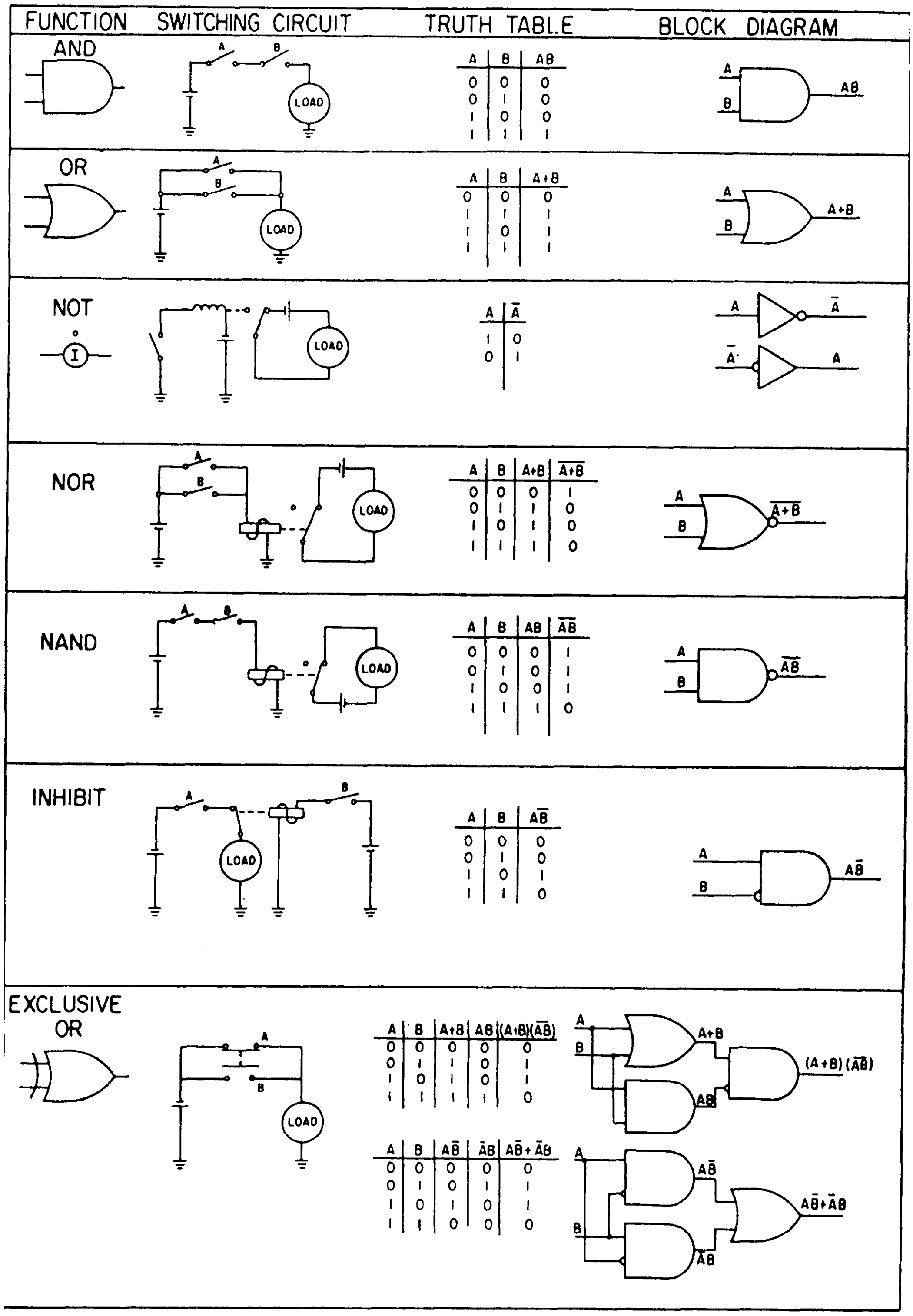


Figure 6-23.—Logic operations comparison chart.

The NOR operation is simply a combination of an OR operation and a NOT operation. In the truth table, the OR operation output is indicated between the input and output columns. The switching circuit and the block diagram also indicate the OR operation.

The NAND operation is a combined operation, comprising an AND and a NOT operation.

The INHIBIT operation is also a combination AND and NOT operation, but the NOT operation is placed in one of the input legs. In the example shown, the inversion occurs in the B input leg; but in actual use, it could occur in any leg of the AND gate.

The EXCLUSIVE OR operation differs from the OR operation in the case where a signal is present at every input terminal. In the OR, an output is produced; in the EXCLUSIVE OR, no output is produced. In the switching circuit shown, both switches cannot be closed at the same time; but in actual computer circuitry, this may not be the case. The accompanying truth tables and block diagrams show two possible circuit configurations. In each case the same final results are obtained, but by different methods.

Basic Logic Diagrams

Basic logic diagrams are used to show the operation of a particular unit or component. Basic logic symbols are shown in their proper relationship so as to show operation only in the most simplified form possible. Figure 6-24 shows a basic logic diagram for a serial subtractor. The operation of the unit is described briefly in the next paragraph.

In the basic subtractor in figure 6-24, assume you want to subtract binary 011 (decimal 1) from binary 100 (decimal 4). At time I_o, the 0 input at A and 1 input at B of inhibitor I_1 results in a 0 output from inhibitor I_1 and a 1 output from inhibitor I_2. The 0 output from I_1 and the 1 output from I_2 are applied to OR gate G_1, producing a 1 output from G_1. The 1 output from I_2 is also applied to the delay line. The I output from G_1 along with the 0 output from the delay line produces 1 output from I_3. The 1 input from G_1 and the 0 input from the delay line produce a 0 output from inhibitor I_4. The 0 output from L and the 1 output from I_3 are applied to OR gate G_2 producing a 1 output.

At time t_1 the 0 inputs on the A and B input lines of I_1 produce 0 outputs from I_1 and I_2. The 0 inputs on both input lines of OR gate G_1 result in a 0 output from G_1. The I input applied to the delay line at time t_o emerges (1 bit time delay) and is now applied to the inhibit line of 13 producing an 0 output from I_3. The 1 output from the delay line is also applied to inhibitor I_4, and along with the 0 output from G_1 produces a 1 output from I_4. The I_4 output is recycled back into the delay line, and also applied to OR gate G_2. As a result of the 0 and 1 inputs from I3, and I4, OR gate G_2 produces a 1 output.

At time t_2, the 1 input on the A line and the 0 input on the B line of I_1 produce a 1 output from I_1 and a 0 output from I_2. These outputs applied to OR gate G1 produce a 1 output from G_1, which is applied to 13 and I_4. The delay line now produces a 1 output (recycled in at time t_1), which is applied to I_3 and I_4. The 1 output from the delay line along with the 1 output from G_1 produces a 0 output from I_3. The 1 output from G_1 along with the 1 output from the delay line produces a 0 output from I_4. With 0 outputs from I_3 and I_4, OR gate G_2 produces a 0 output.

Detailed Logic Diagrams

Detailed logic diagrams show all logic functions of the equipment concerned. In addition, they also include such information as socket locations, pin numbers, and test points to help in troubleshooting. The detailed logic diagram for a complete unit may consist of many separate sheets, as shown in the note on the sample sheet in figure 6-25.

All input lines shown on each sheet of a detailed logic diagram are tagged to show the origin of the inputs. Likewise, all output lines are tagged to show

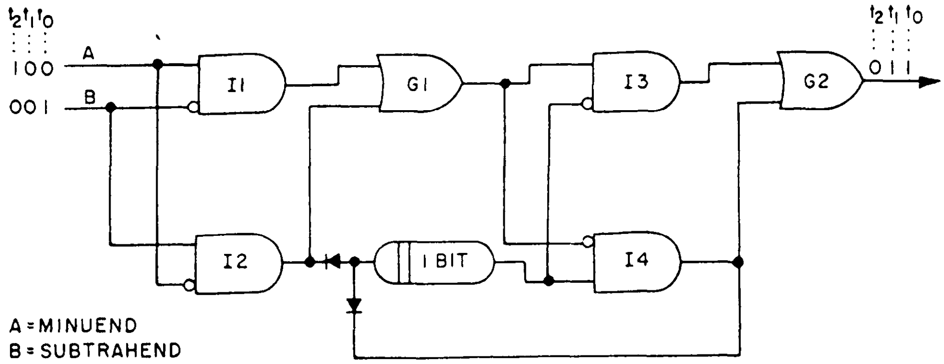


Figure 6-24.—Serial subtractor, basic logic diagrams.

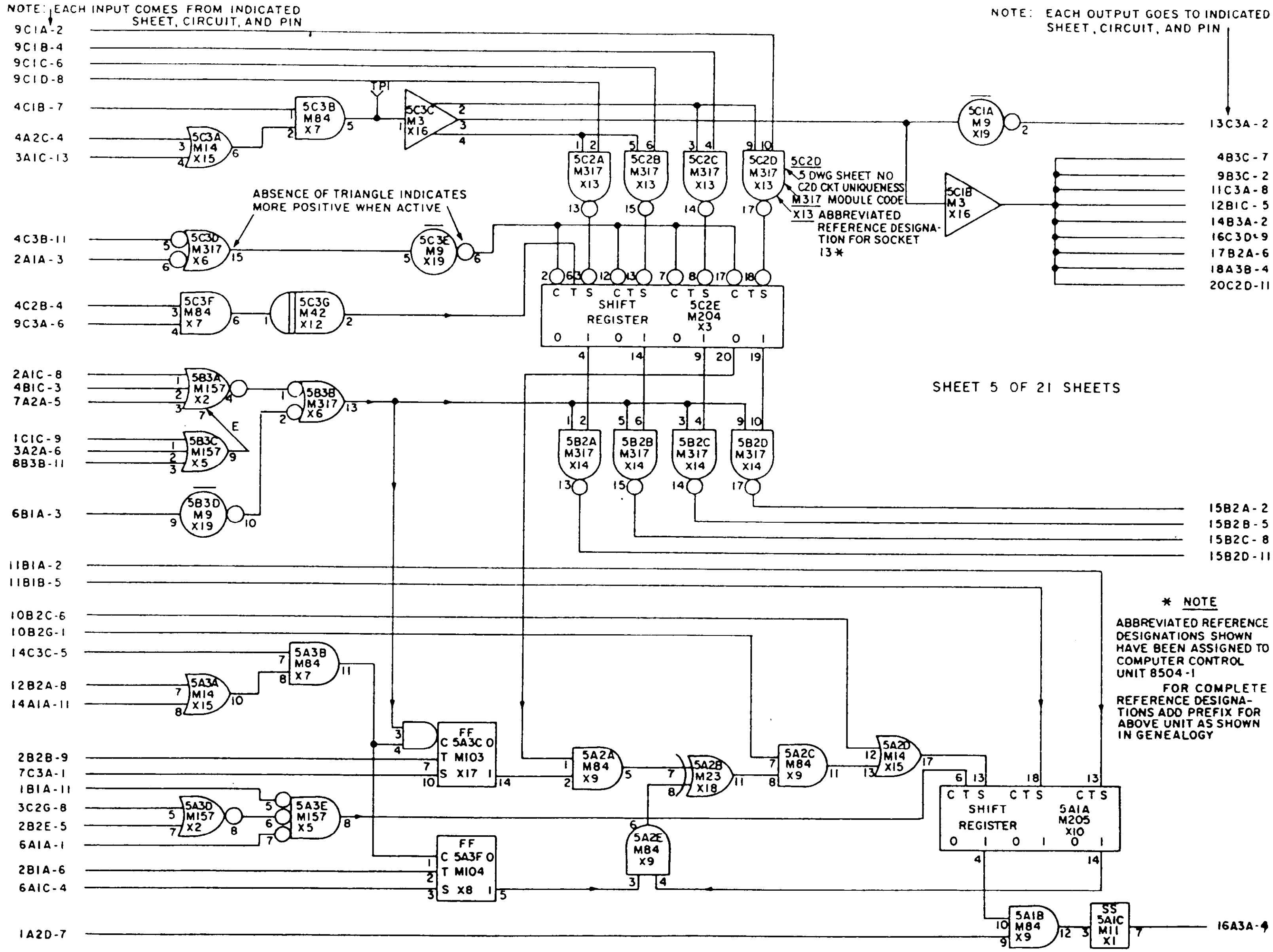
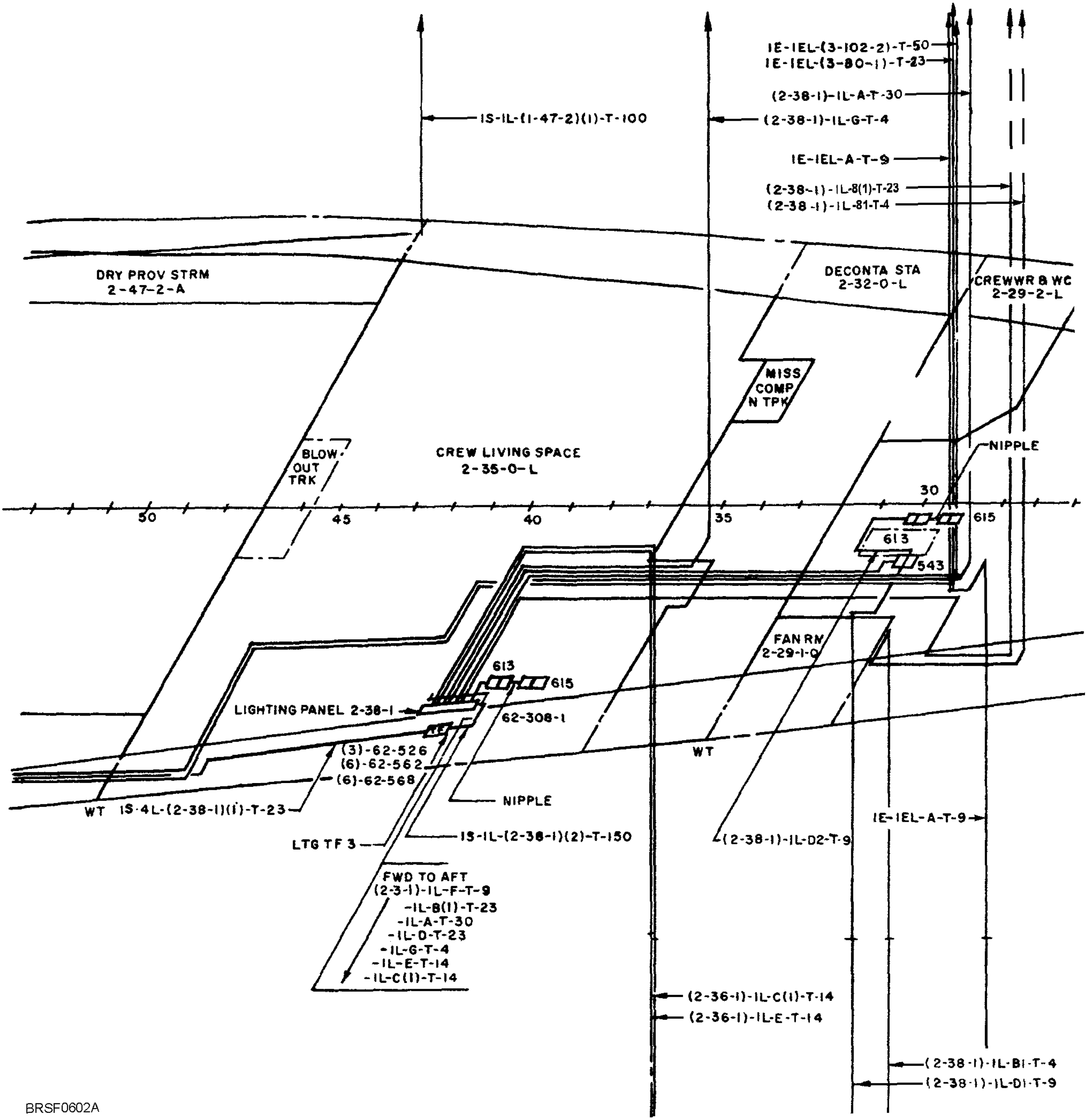


Figure 6-25.—Sample detailed logic diagram.

destination. In addition, each logic function shown on the sheet is tagged to identify the function hardware and to show function location both on the diagram and within the equipment.

For example, in the OR function 5C3A at the top left in figure 6-13, the 5 identifies sheet number 5, C3 the drawing zone, and A the drawing subzone (the A section of module 5C3). The M14 is the module code number, which identifies the circuit by drawing number. The X15 is the partial reference designation, which when preceded by the proper reference designation prefix, identifies the function location within the equipment as described earlier.



1E-1EL-(3-102-2)-T-50
1E-1EL-(3-80-1)-T-23
(2-38-1)-1L-A-T-30
1S-1L-(1-47-2)(1)-T-100
(2-38-1)-1L-G-T-4
1E-1EL-A-T-9
(2-38-1)-1L-8(1)-T-23
(2-38-1)-1L-81-T-4
DRY PROV STRM
2-47-2-A
DECONTA STA
2-32-0-L
CREWWR & WC
2-29-2-L
MISS
COMP
N TPK
BLOW
OUT
TRK
CREW LIVING SPACE
2-35-0-L
NIPPLE
30
50
45
40
35
615
613
543
FAN RM
2-29-1-0
613
615
LIGHTING PANEL 2-38-1
62-308-1
(3)-62-526
(6)-62-562
(6)-62-568
WT
WT
1S-4L-(2-38-1)(1)-T-23
NIPPLE
1E-1EL-A-T-9
LTG TF 3
1S-1L-(2-38-1)(2)-T-150
(2-38-1)-1L-D2-T-9
FWD TO AFT
(2-3-1)-1L-F-T-9
-1L-B(1)-T-23
-1L-A-T-30
-1L-D-T-23
-1L-G-T-4
-1L-E-T-14
-1L-C(1)-T-14
(2-36-1)-1L-C(1)-T-14
(2-36-1)-1L-E-T-14
(2-38-1)-1L-B1-T-4
(2-38-1)-1L-D1-T-9

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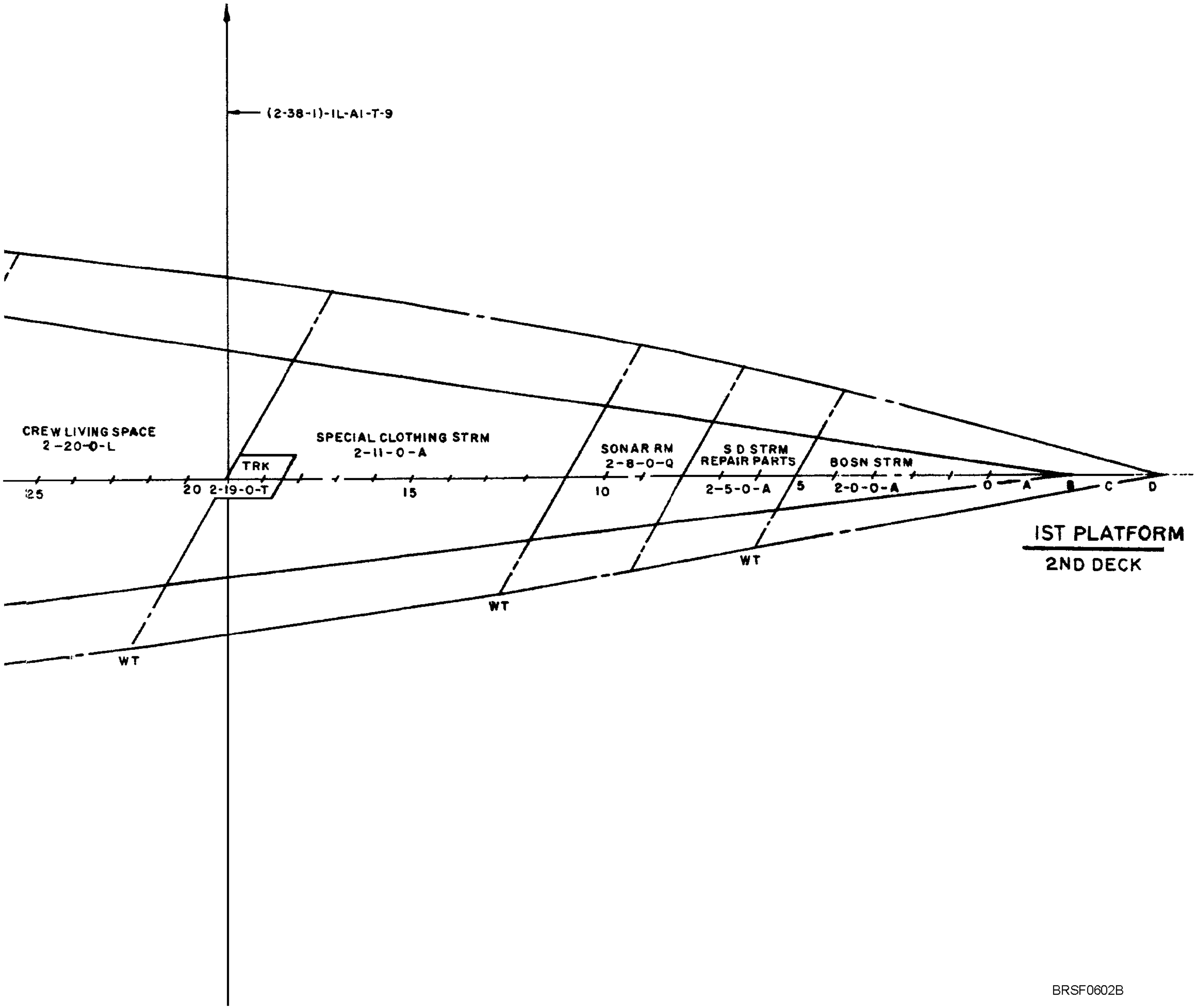
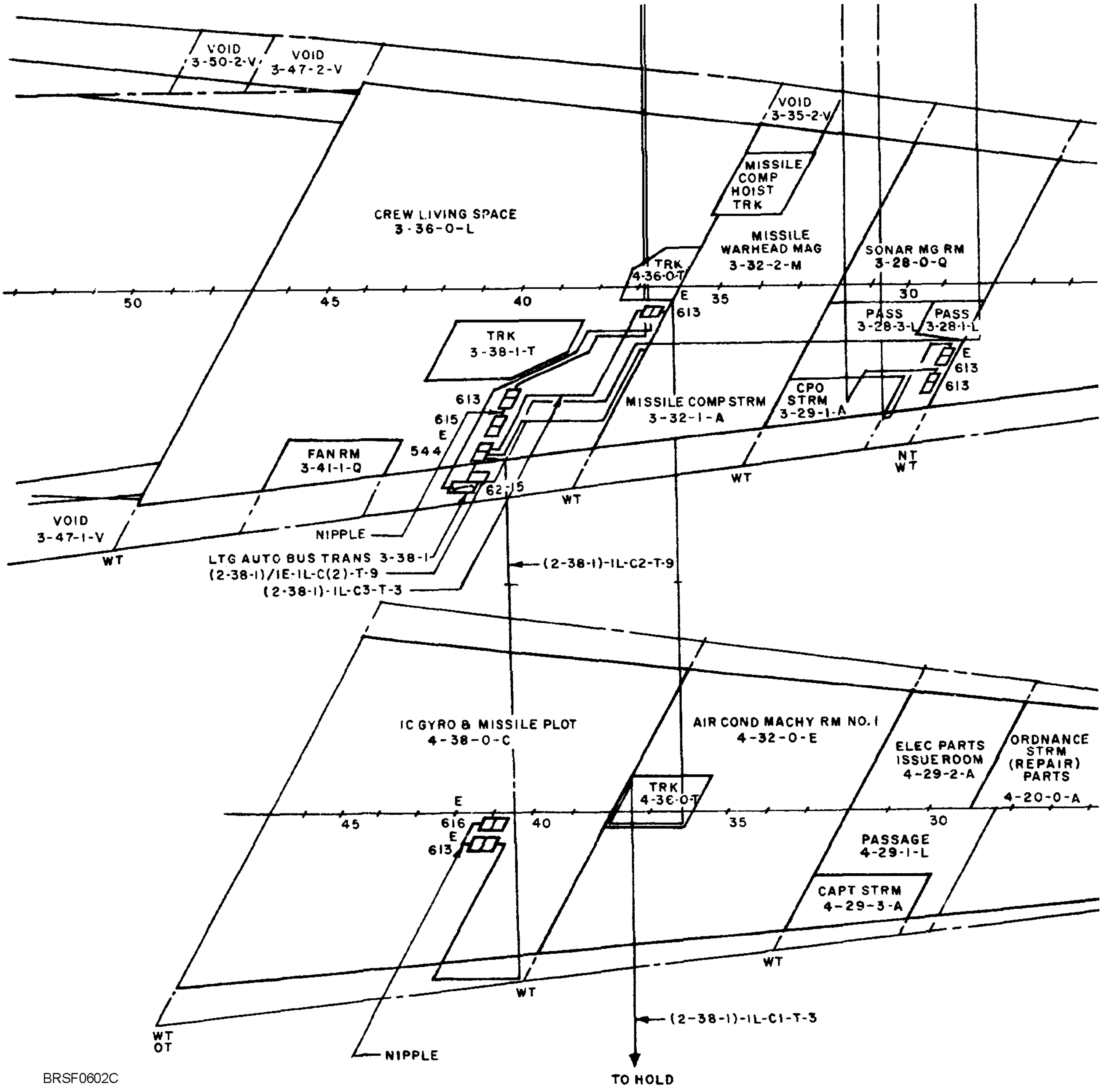
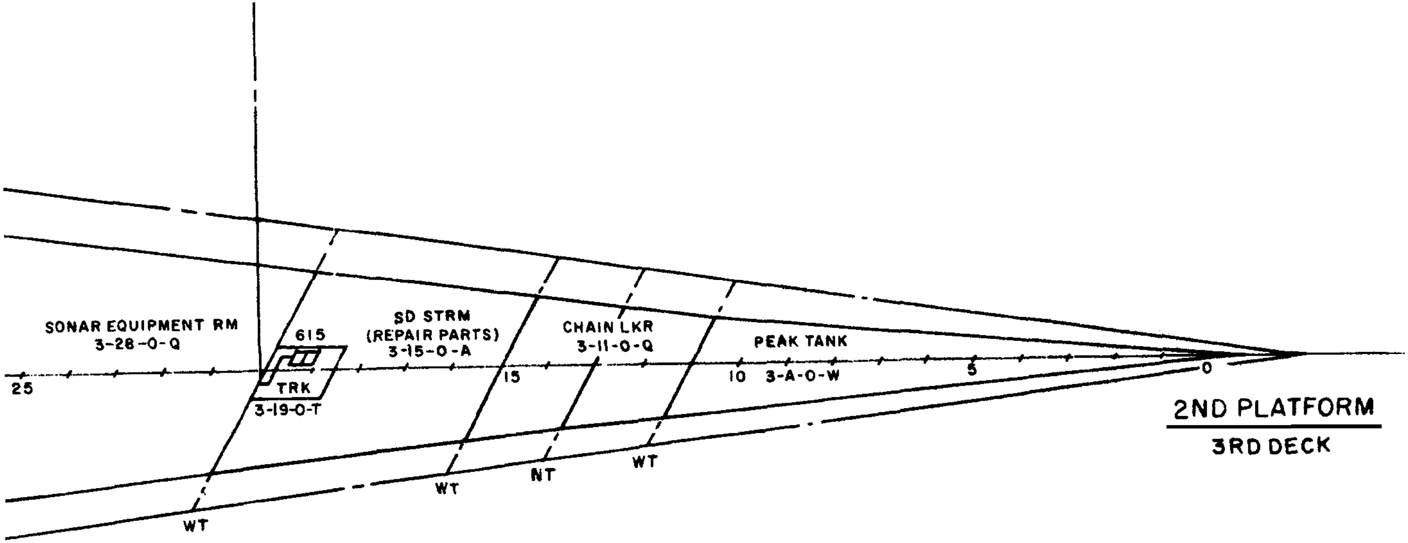
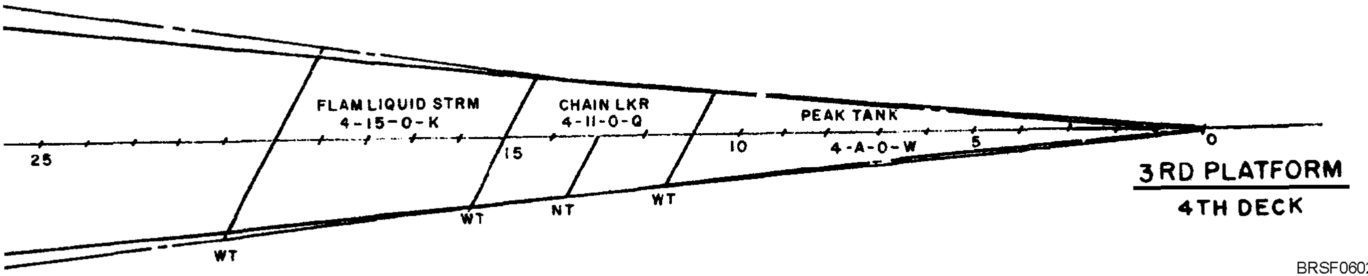

(2-38-1)-1L-A1-T-9
CREW LIVING SPACE
2-20-0-L
SPECIAL CLOTHING STRM
2-11-0-A
SONAR RM
2-8-0-Q
S D STRM
REPAIR PARTS
2-5-0-A
BOSN STRM
2-0-0-A
TRK
2-19-0-T
25
20
15
10
5
0
A
B
C
D
WT
WT
WT
WT
1ST PLATFORM
2ND DECK
BRSF0602B


VOID
3-50-2-V
VOID
3-47-2-V
VOID
3-35-2-V
MISSILE
COMP
HOIST
TRK
CREW LIVING SPACE
3-36-0-L
MISSILE
WARHEAD MAG
3-32-2-M
SONAR MG RM
3-28-0-Q
TRK
4-36-0-T
E
613
50
45
40
35
30
PASS
3-28-3-L
PASS
3-28-1-L
TRK
3-38-1-T
E
613
613
613
615
E
544
CPO
STRM
3-29-1-A
MISSILE COMP STRM
3-32-1-A
FAN RM
3-41-1-Q
62-15
NT
WT
WT
WT
VOID
3-47-1-V
WT
NIPPLE
LTG AUTO BUS TRANS 3-38-1
(2-38-1)/1E-1L-C(2)-T-9
(2-38-1)-1L-C3-T-3
(2-38-1)-1L-C2-T-9
IC GYRO & MISSILE PLOT
4-38-0-C
AIR COND MACHY RM NO. 1
4-32-0-E
ELEC PARTS
ISSUE ROOM
4-29-2-A
ORDNANCE
STRM
(REPAIR)
PARTS
4-20-0-A
TRK
4-36-0-T
E
616
E
613
45
40
35
30
PASSAGE
4-29-1-L
CAPT STRM
4-29-3-A
WT
WT
WT
OT
NIPPLE
(2-38-1)-1L-C1-T-3
TO HOLD

BRSF0602C


SONAR EQUIPMENT RM
3-28-0-Q
615
TRK
3-19-0-T
SD STRM
(REPAIR PARTS)
3-15-0-A
CHAIN LKR
3-11-0-Q
PEAK TANK
3-A-0-W
25
15
10
5
0
WT
WT
NT
WT
2ND PLATFORM
3RD DECK


FLAM LIQUID STRM
4-15-0-K
CHAIN LKR
4-11-0-Q
PEAK TANK
4-A-0-W
25
15
10
5
0
WT
WT
NT
WT
3RD PLATFORM
4TH DECK

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